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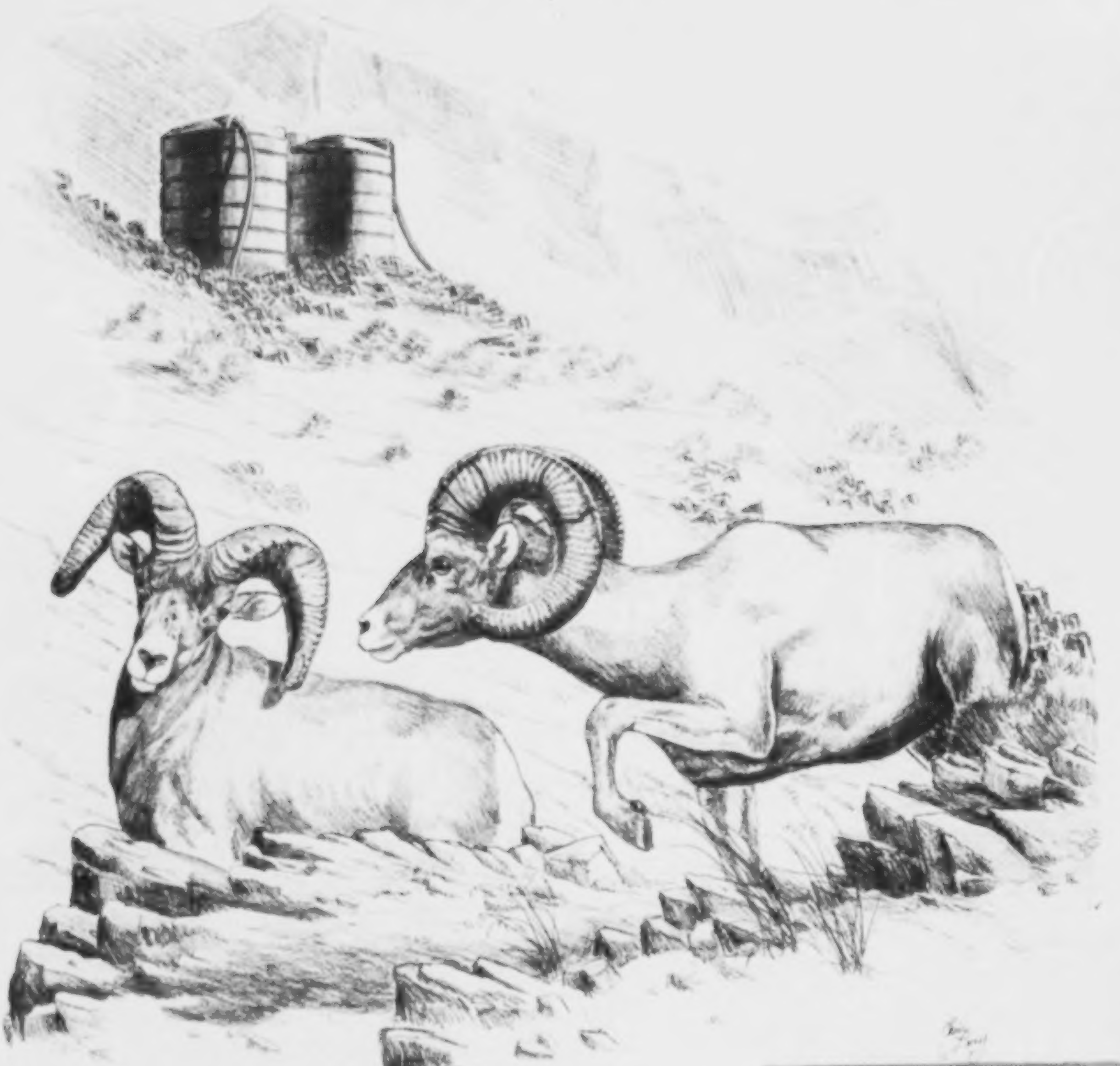
WILDLIFE WATER DEVELOPMENT



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WILDLIFE WATER DEVELOPMENT

EDITED BY

GEORGE K. TSUKAMOTO
SAN JUAN STIVER

A Proceedings of the
Wildlife Water Development Symposium
Held In
Las Vegas, Nevada
November 29, 30 and December 1, 1988

Sponsored by

The Wildlife Society - Nevada Chapter
U. S. Bureau of Land Management - Nevada
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1990

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ACKNOWLEDGEMENT

The need for a Wildlife Water Development Symposium was an often discussed topic at many of the gatherings of biologists and habitat managers throughout the west. Many agencies were actively engaged in developing water for wildlife, independent of each other. In Nevada emphasis was initially placed with improvement of upland game bird habitat, but more recently work was directed towards development of water for big game such as desert bighorn sheep and pronghorn antelope. Increasingly, water development has been suggested as a form of mitigation for losses in wildlife habitat elsewhere. It became readily apparent that a need existed to provide a forum to share in the technical aspects of this work with the leading experts in the west. With this objective in mind an ad hoc Committee of the Western Section of The Wildlife Society was organized for the purpose of organizing and holding a water development syposium. This Committe consisted of George Tsukamoto, Chairman, William R. "Rick" Brigham, Donald A. Klebenow and Vernon C. Bleich. Many individuals contributed to the success of this symposium, and we are extremely thankful and appreciative. Without the Coordinated efforts of Robert Turner, President of the Nevada Chapter of The Wildlife Society, Dave Goecoechea, Staff Biologist, Nevada State Office of the Bureau of Land Management and the Game Division Staff of the Nevada Department of Wildlife this symposium could not have been possible. A special thanks goes to the Bureau of Land Management for the printing of this publication.

We would like to thank all the authors for contributing to this publication and taking the time to write down their thoughts, ideas and conclusions. A special thank you to Dawn Anderson, Nevada Department of Wildlife, Game Division Secretary for her skill and effort in formatting all of the papers including the importation of graphics and general preparation for camera ready copy. San Stiver, Staff Biologist for the Nevada Department of Wildlife deserves special recognition for his part in the organization and final preparation of this publication. Finally, we dedicate this publication to all, biologist and volunteers alike, who have labored to improve wildlife habitats through water development.

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INTRODUCTION

The Wildlife Water Development Symposium was organized in an attempt to focus on the current state of the art in the development of water for wildlife. Wildlife biologists throughout the arid west have attempted to improve habitat conditions for wildlife, recognizing the fact that water was a key element that was often in short supply. Joseph Grinnell, in 1927, was one of the first biologists to point out water as being a prime limiting factor for quail in the desert regions of the Southwest. Ben Glading of the California Fish & Game Department took it one step further when he began to design and develop artifical watering devices for wildlife. He coined the phrase "gallinaceous guzzler" referring to a self-maintaining watering unit. The effort initiated by Glading in 1942 and others who soon followed in the development of new man made watering sites and improvements of existing watering places such as natural springs, seeps, water holes was the beginning of the work we now call wildlife water development.

Following the lead of Glading, in the development of waters for desert quail, many wildlife agencies engaged in a flurry of activity to develop guzzler with the sole intent of increasing game bird populations. Many innovative thoughts were converted to practical design and tested in the field. At the same time modern technology over the years has produced superior products for building artificial watering devices and improving natural watering sites. As a result there has been a proliferation of ideas and techniques that save time, money, or improve the developments serviceability and/or efficiency.

The purpose of the Wildlife Water Development Symposium was to assemble representatives from agencies, the business community, and wildlife organizations to discuss current techniques, materials and designs and to share successes as well as failures in the development of waters for wildlife. The symposium was held at the Holiday Inn Hotel, 3475 S. Las Vegas Blvd., Las Vegas, Nevada, on November 29, 30 and December 1, 1988. The symposium was jointly sponsored by The Wildlife Society-Nevada Chapter, Nevada Department of Wildlife and the U.S. Department of Interior, Bureau of Land Management-Nevada State Office.

In total, twenty-four papers are included in these transactions covering four basic water development topics as follows; Techniques, Evaluation, Cost/benefit and Volunteers.

Approximately 110 people attended the symposium where considerable exchange of ideas and experiences were met. A field trip was held on the third day to visit a bighorn sheep slick-rock development located on BLM lands south of Las Vegas in the McCullough Mountains.

Techniques

SOIL CEMENT APPLICATION FOR WILDLIFE DEVELOPMENTS AND RANGE DEVELOPMENTS
(WATER HARVESTING/COLLECTION)

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INTRODUCTION

Soil cement is a simple, highly compacted mixture of soil, Portland cement, and water. As the cement hydrates, the mixture becomes a hard, durable paving material, or in the process to be explained in this article, a water tight repellent mixture to collect and/or hold precipitation. ie. rain or snow melt. This is not a new process by any means, but it may be in the area of water harvesting and collection.

In the early 1920's, state highway departments in Iowa, South Dakota, and Ohio tried this concept to try to strengthen subgrades and roadway soils. About the same time, California and Texas built short sections of roads using this process.

In 1935, the Portland Cement Association cooperated in building a 1.5 mile experimental project - an effort shared by the South Carolina State Highway Department and the U.S. Bureau of Public Roads. From this work, other states in 1936, Michigan, Illinois, Wisconsin, and Missouri built soil-cement roads.

Compared to today's construction standards, all this work was crude, but as of the 1950's, all of these roads were still carrying traffic (Copyright 1958 by Portland Cement Association).

METHODS

From this brief introduction, I will try to adapt this road construction technique to the area of water collection/harvesting and storage in areas where the soils lack clay to construct a reservoir or water harvester in the low precipitation zones of the western desert regions as well as any other appropriate location where water storage is a problem.

The first thing the resource specialist, concerned with water for livestock/wildlife, must determine is the amount of water needed and the location for the best utilization of the water development. Next a soils specialist will need to determine the soil classification (unified soil classification) A-1 through A-7. The optimum moisture content needed to obtain maximum compaction of the material to be mixed. Once this is done, the amount of Portland Cement I or II can be determined from the following Table I.

The cement content is usually easier to give in percent by volume of compacted mixture. For a specified cement content of 8% by volume, the cement requirement for 1 square yard of soil-cement 6 inches in compacted thickness is 3 ft. x 3 ft. x 1/2 ft. x 0.08, or 0.36 bags of cement (one bag of cement = 1 cu. ft.). This would equal 33.8 lbs of Portland Cement per square yard (0.36 x 94 lbs. the weight of one bag of cement.)

The research done in the 1920s - 1950s was mainly for road construction needs and to test strength and durability. The information currently available and published in 1958 by the Portland Cement Association indicate the roads have lasted at least 20+ years.

When I first started I referenced a 1974 US Forest Service specification for "Sacked Soil Cement" to be used in lieu of riprap. The sacked soil-cement was used in the place of rock to be placed around culverts to stop erosion from high water. (Sacked-Burlap Bags).

If the material could hold fillbanks in place, stacked around a culvert in water (no penetration of water) then why couldn't I make an apron to collect water from precipitation in remote areas for wildlife or even cattle? When I say "even cattle" it is not to say their need is of any less importance, but the size and storage

Table 1. Normal range of cement requirements for "Band (C) Horizon Soils (a).

AASHTO Unified Soil Group (M-145)	Per Cent By Volume	Per Cent By Weight
A-1a	5-7	3-5
A-1b	7-9	5-8
A-2	7-10	5-9
A-3	8-12	7-11
A-4	8-12	7-12
A-5	8-12	8-13
A-6	10-14	9-15
A-7	10-14	10-16

(a) "A" horizon soils may contain organic or other materials detrimental to cement reaction and may require higher cement factors. For dark grey to grey "A" horizon soils, increase the above cement contents four (4) percentage points; for black "A" horizon soils, six (6) percentage points. (Copyright 1958 by Portland Cement Association)

needs are 4 to 5 times greater per animal than wildlife.

I used the US Forest Service 1974 specification which uses the Portland Cement see Table #1 but with some closer tolerances, See Table #2.

The next step was to find an area to try the process on a small scale to see if the material would last and keep the cost to a minimum for the experimental plot. The location of the experimented water-harvester is approximately 2 miles west of Oakley, Idaho on a small 10-15 cow BLM permit.

This area normally receives 2"-4" of precipitation (rain) in the time frame of the grazing permit (April - June).

It was calculated that the cattle needs would be approximately 225 gallons per day based on a 15 gallon need per day per animal or a 13,500 gallon need for the 60 day spring use period. At a 4" maximum precipitation, it would take a 5,417 square foot apron to collect sufficient water.

Table 2. Modified Cement Requirements

AASHTO Classification (M-145) Soil Group	Percent Cement By Volume
A-1a	7
A-1b	9
A-2	10
A-3	12
A-4	12
A-5	13
A-6	14
A-7	15

The following formula was used:

KNOW "NEED-13,500 gal/4" precipitation

$$\frac{13{,}500}{7.479 \text{ gal/cu.ft.}} = 1805 \text{ cubic feet}$$

$$4'' \times X = 1805$$

$$X = \frac{1805}{.3332}$$

Apron Size X = 5217 square feet.

Based on these calculations it was determined that the large size required for underground water storage was not feasible and the overall cost of the project was prohibitive.

Instead, we settled on an 850 gallon surplus BLM fire engine water tank with troughs which equal a total storage of 1250 gallons and a 900 square foot apron which would collect a total of 2250 gallons during the period of use.

Process and Construction Techniques Used

1. A site is selected which will allow for the installation of a underground storage tank.
    - a) Soils checked to determine classification.
    - b) Percent cement determined (7-15%).
2. Rainfall amounts and time of use must be determined. Calculate apron size based on storage available.
    - a) Inches/year (or time of use) X catchment size X 7.5 gal/cu. ft. of area = storage capacity.
    - b) Amount to be used by numbers of animals.
3. Construction began by marking the dimesions of the apron and locating the sites for the water storage tank and drinker.
4. The required amounts of cement was applied in four semi-equal applications and ;mixed into the soil with a tiller.
5. The soil cement mixture is throughly tilled and raked into place to form a smooth collection surface.
6. The vibrator compactor was used twice on the apron, after which only watering was continued. A 1000 gallon fire pumperwas used to apply the water at approximately two gallons per cubic feet of mixture.
7. The top soil, which was removed previously, is now used to construct a berm to stopwater from flowing overland and on to the collection surface.
8. The next day an additional 300 gallons of water was applied to the collection surface.

On the seventh day of construction, light rain showers fell. After the soil cement apron cured for eight days an additional 250 gallons of water was applied using a pumper tanker. After five to ten seconds of surface wetting, the water began to run off and collect in the storage tank.

EVALUATION

On April 5, 1988, approximately eight months later, the site was revisited. The following assessment was made.

1. It was learned from the residents of the area that no measurable rain was recorded since 1987.
2. The rain gauge at the site showed approximately 3.6 inches of precipitation in the form of snow.
3. The storage tank had approximately 350 gallons of water stored. This would indicate approximately 100 gallon/1" of snow melt, or a 20% water content.
4. After eight months of freezing, thawing, wet and dry conditions the apron is in good condition.
5. There was some damage noted to the dike along the outside edges.

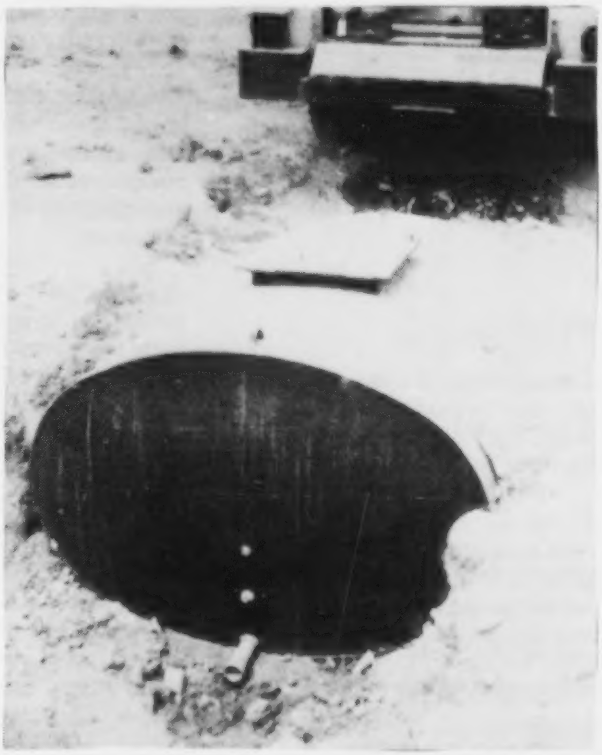

Figure 1. A site was selected and excavated to install the storage tank.

Figure 2. The storage tank is installed.

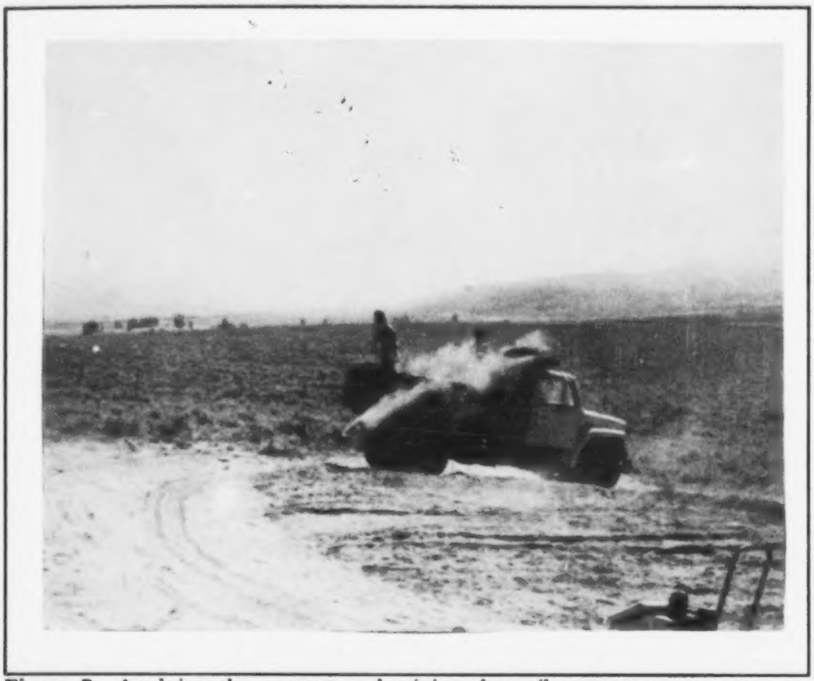

Figure 3. Applying the cement and mixing the soil cement.

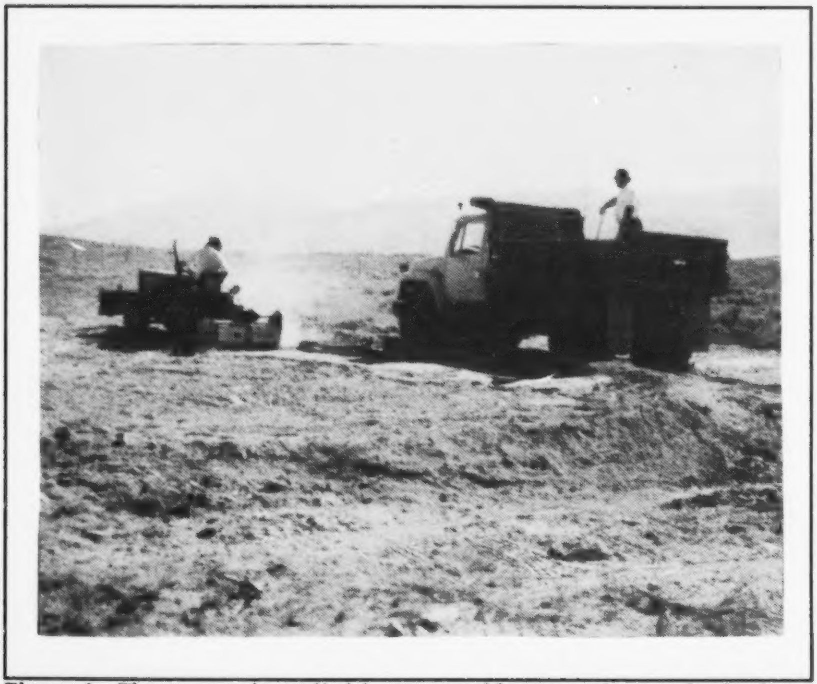

Figure 4. The cement is applied in manageable proportions and mixed.

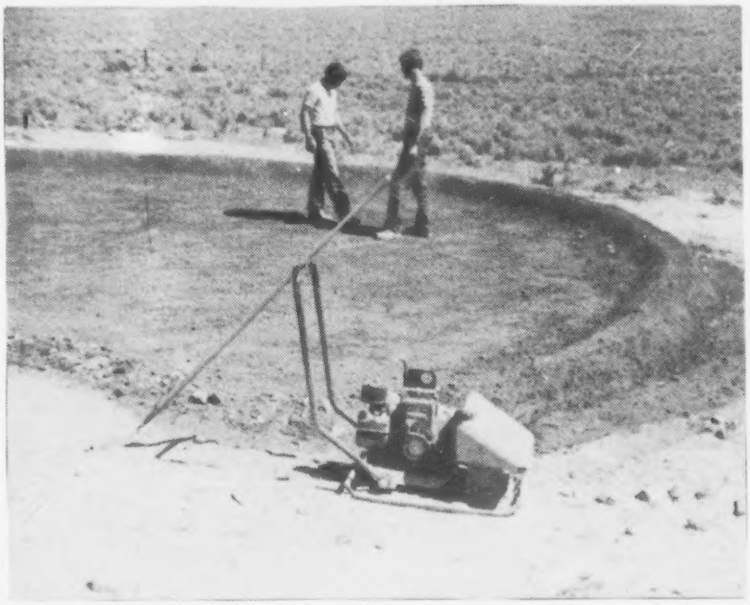

Figure 5. Tilling and raking the mixture into place.

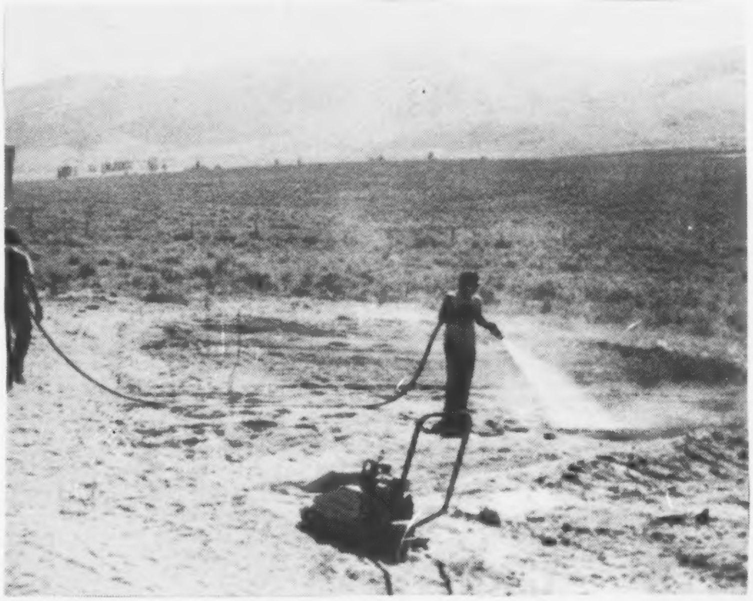

Figure 6. Compaction and final watering step is begun.

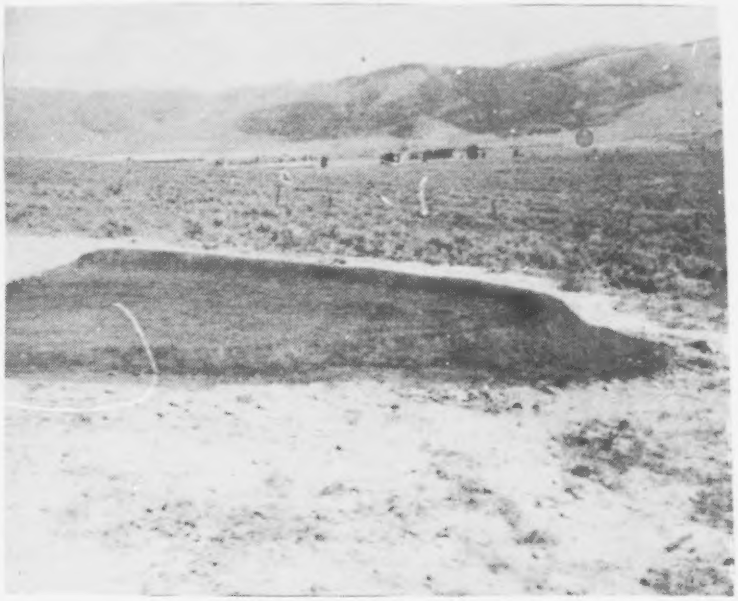

Figure 7. After vibrating compactor was used twice, only watering continued.

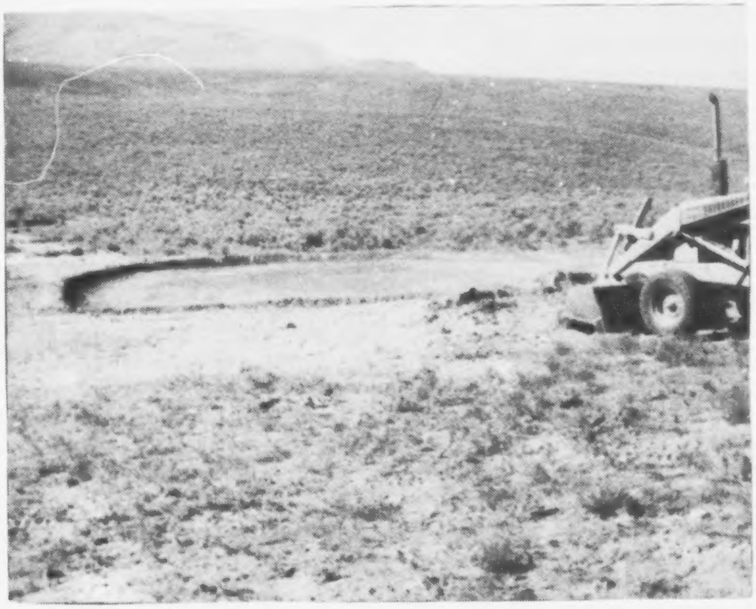

Figure 8. Top soil is used to contruct a berm.

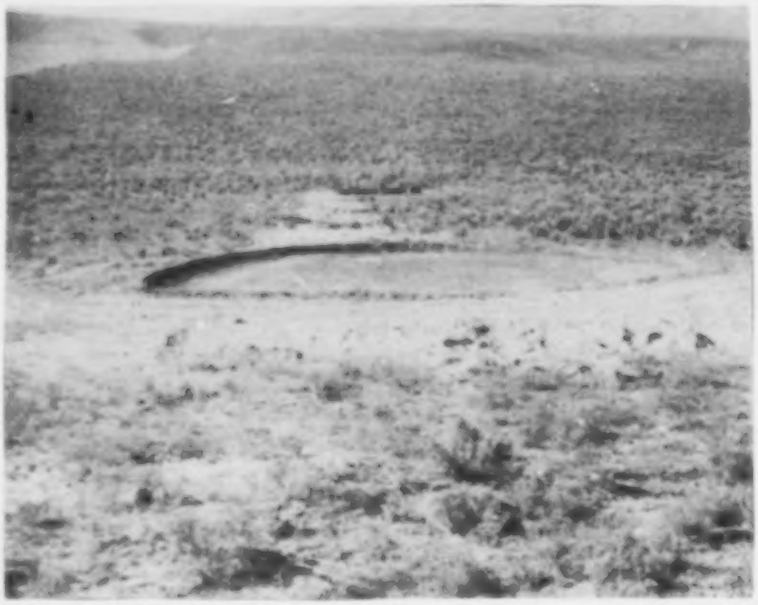

Figure 9. The finished product.

DESIGNED NATURAL APPEARING CEMENT STRUCTURES FOR WET AREA ENHANCEMENT

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Abstract

The Prescott National Forest has recently employed a shotcrete process in a highly successful wildlife habitat improvement project. The shotcrete process was applied by the use of a large volunteer workforce in the construction of four in-stream retention structures. The method met the wet area enhancement objectives while successfully addressing aesthetic concerns. Shotcrete is both a material and an application method. The material is concrete, mortar or grout. The method is the application of this material by pneumatic pressure through a specially adapted hose. The concrete is literally "shot" into and around a steel reinforcement network in the location where it is to harden. This paper describes project site selection and design and construction. Livestock management and volunteer contributions as affected by the shotcrete method are discussed. Comparisons are made with other construction techniques.

INTRODUCTION

The Connell Mountain Wildlife Habitat Improvement Project was implemented in 1988 on the Chino Valley Ranger District, Prescott National Forest. A new application of the use of shotcrete, an existing technique, was used to construct four instream sediment retention structures.

OBJECTIVES

The objective of the project was to enhance wildlife habitat on the project area through the creation of water development areas capable of producing early spring forage. These habitat elements were determined to be limiting factors for Merriam's turkey, an important species in the area. Other indigenous species such as elk, mule deer, and non-game species were also considered. Stream bed restoration is also an objective for the area, which contains many scoured and eroding water courses.

METHOD

The Chino Valley Ranger District has experience in developing waters and early spring forage through the placement of impermeable instream structures to create wet meadows. Masonry, poured concrete, and now shotcrete structures have been used to retain nutrient rich sediments and water, and to restore eroded streambeds and create wet meadows.

SITE SELECTION

Characteristics of an ideal site for structure placement include a narrow rock notch in competent bedrock on a low gradient stream to minimize structure size and cost while maximizing the area affected. The sites accessibility is also an important consideration. Precipitation levels and sufficient watershed size above the site to generate flows needed to charge the system is another important consideration. It is strongly recommended that a hydrologist be involved in the site selection phase of these projects.

DEVELOPMENT TECHNIQUE

Upon selection of a suitable site, a cross sectional survey of the rock notch and a profile of the upstream segment of the stream should be conducted. The cross section of the notch will be necessary for determining design specifications. Some excavation may be necessary. It is strongly suggested that an engineer with structural experience be involved in this aspect. The upstream profile will assist in determining the area to be affected by varying structure heights.

The above considerations are common to all the types of structures previously mentioned. The balance of this paper will deal primarily with the shotcrete application utilized in the Connell Mountain Wildlife Habitat Improvement Project with some comparison to the other techniques mentioned.

SHOTCRETE

Shotcrete is a term used to describe both a material and a method. The material is concrete, mortar or grout. The method is the application of this material by pneumatic pressure through a specially adapted hose. The concrete is literally shot into place against the form and around the reinforcement network. The shotcrete process is commonly used in the construction of swimming pools and in the general construction industry for fire-proofing steel members, floor and roof slabs, building walls, and for covering brick, tile, or old concrete walls. The process has also been used in lining reservoirs.

The shotcrete process was suggested and selected as the technique to be used in the Connell Wildlife Habitat Improvement Project as a means of addressing aesthetic concerns as well as lending itself to the use of a large volunteer workforce which evolved in the development of this project.

PROJECT DEVELOPMENT

Upon project approval and receipt of designs the first step in the construction process involved the drilling and placement of 5/8" rebar into bedrock to pin the structure to bedrock. 5/8" holes were drilled with rock drills and 5/8' rebar was compression driven into the holes to insure a secure grip. The design specified a double row of pins 8 inches apart with 16 inch spacing offset and one foot deep into the granitic bedrock. Twelve inches of rebar was specified to extend above the surface to tie to the steel reinforcment matting of the structure.

The next step involved constructing the backing that the shotcrete was to be shot against. We chose a combination of sandbags and plywood backing (Figure 1). Sandbags were selected due to the onsite availability of sand and ease of placement into the irregular shaped base. We topped the sandbags with braced plywood panels because of the tendancy of sandbags to topple over at the heights desired for the finished structures. The plywood panels were easily constructed and fitted to the relatively flat surface of the top of the sandbags. Creativity in the choice of backing is quite feasible.

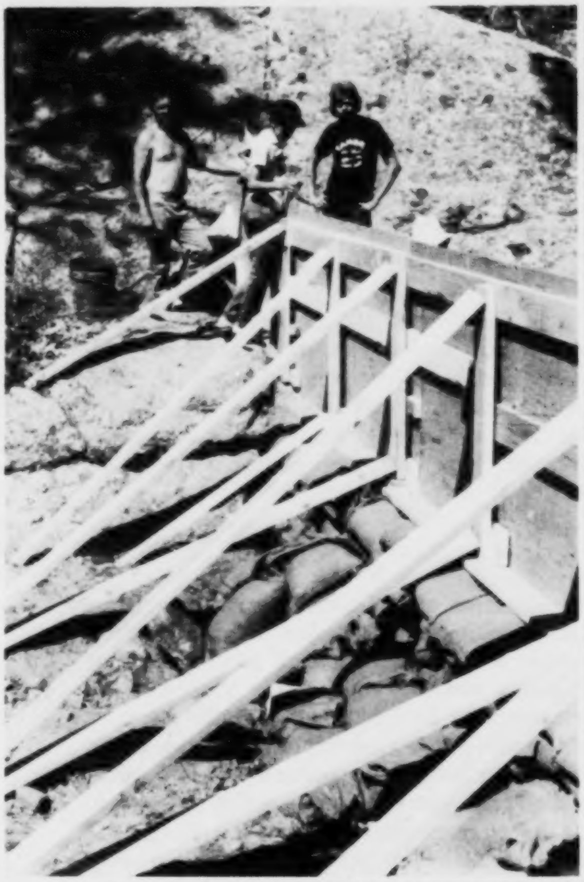

Figure 1. Construction of the backing against which the shotcrete will be shot. Plywood has been braced on top of the wall of sandbags.

The next step involved the placement of the designed rebar matting tied to the bedrock pinning and suspended from the backing (Figure 2). Buttresses were included in each of the design specifications to break the moment of the lateral forces and to prevent toppling. Pipes were placed in the base to allow drainage of the structures or to provide for offsite transport of water at a future date.

The next step involved the actual shotcrete application of batch dyed concrete against the backing (Figure 3). Standard concrete color tiles were used in specifying the type and amount of dye used to match the surrounding rock. To create natural appearing structures the structures were shot with varying degrees of irregularity. Because the shotcrete sets up rapidly, green and black dyes were splashed on immediately after application to simulate lichens and natural oxide stains. Trowels were used to scribe simulated fissures into the surface. Crushed mica from a nearby source was also thrown on the surface to simulate the sparkling crystals typical of natural granite. Artistry was applied in these applications.

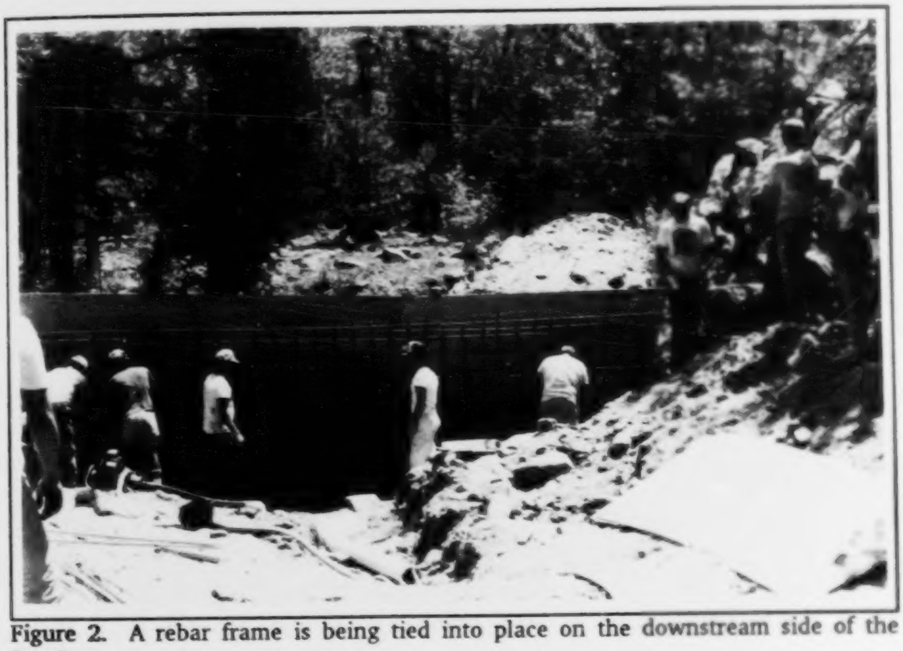

Figure 2. A rebar frame is being tied into place on the downstream side of the framing.

Finally, the forms were removed, pipes were capped, and the sites were cleaned up (Figure 4).

ADVANTAGES, DISADVANTAGES OF SHOTCRETE

Besides the obvious advantage of creating natural appearing structures, shotcrete has a higher cure strength and faster cure than regular concrete. This is due to a lack of voids from the high pressure application (150 psi) and the use of a much drier mix. A 2 1/2" slump is characteristic of shotcrete as compared with 7" or 8" for concrete. This was displayed on the day the final two structures were to be shot. Unexpected heavy rains and floods occurred which overtopped the structures shot the previous day. One structure was overtopped by floods two hours after it was shot with no apparent adverse effects. The final structure was shot as an arch over a torrent of water and later plugged when flows subsided. The luxury of interrupting the project until better conditions prevailed was not feasible as the concrete truck was already enroute. In essence, the shotcrete process saved the day. It is highly doubtful that poured structures could have withstood the conditions encountered.

The other primary advantage of using the shotcrete process was the relative ease of forming the structures. This facilitated the use of a large volunteer workforce.

A disadvantage of the shotcrete process is the cost involved with the services and equipment needed. This amounted to $3000.00 on our project or an average of $750.00 per structure. This cost was contributed in our project through the Challenge Cost-Share Program.

An additional cost involved the use of additional concrete to create the irregular surface finish. We used a total of 53 yards of concrete in the four structures. A similar project in 1986 involving 3 comparably sized poured structures utilized a total of 28 yards. Overall Forest Service costs were lower for the 4 shotcrete structures ($15,000.00) than the 3 poured structures ($16,000.00) due to volunteer contribution of labor and materials, less forming materials because of the need to form only one side, quicker forming, and lower unit cost of concrete including the batch dye. The cost and amount of rebar was comparable between the two projects.

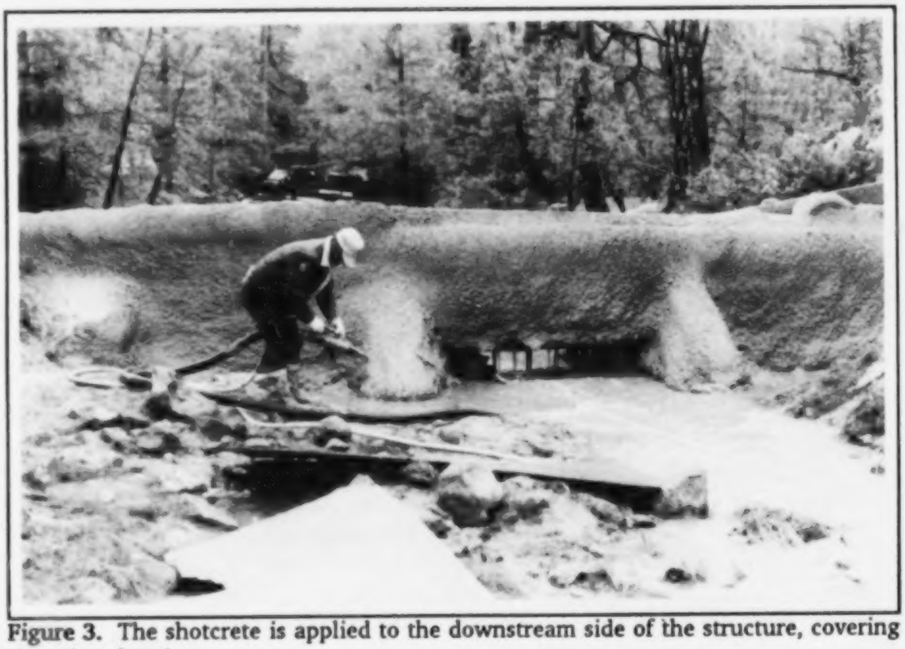

Figure 3. The shotcrete is applied to the downstream side of the structure, covering the rebar framing.

ENVIRONMENTAL BENEFITS

In addition to the benefit of enhancing wildlife values, these wet area enhancement structures increase the value of many other resources.

Many streambeds in our area are scoured due to effects of historic overgrazing and the high intensity storms we receive. We have utilized many other types of instream structures in attempts to rehabilitate water courses including earthen, gabion, wooden, and metal structures. These structures have their place in our management efforts, but where suitable bedrock sites exist, concrete structures have two primary advantages, long and maintenance-free lifespan and retention of water and sediment.

Upstream from the structures nutrient rich sediment is trapped creating a sponge in which water is retained. The wet sponge becomes densely vegetated with grasses, forbs, and other water loving plants. These areas tend to green up early in the spring when much of the surrounding forest is dry and brown due to lack of winter and early spring moisture. This verdant growth is high in Vitamin A, a nutrient vital to wildlife especially during their breeding and gestational periods of the reproductive cycle.

Areas downstream from the structures also benefit. The area below the structures will also aggradate sediment due to the reduction in the velocity of the flow of water. In most cases the structures will leak either at the base or as seepage through fissures in the bedrock. The slow release of water promotes plant growth in the channel below the structure. Riparian species will benefit from the extended duration of flows. Small diameter drain pipes can be installed at the base of the structures to insure that a constant low volume flow is maintained in the watercourses below the structure. This increases the availability of water for wildlife.

The structures provide recreational opportunities to the public. They provide pools for swimming for several years until they silt in. They provide the opportunity to picnic or camp near water, a relatively rare commodity in Arizona. They also offer the opportunity to observe wildlife, a popular pastime for many people. The primary advantage of using the shotcrete process in this aspect is that it allows the function to be achieved in an aesthetically pleasing manner.

GRAZING MANAGEMENT CONSIDERATIONS

The range resource and range management will benefit through the improved distribution of dependable waters. We have only considered placing these structures in areas where we have effective grazing management. Placement in small pastures that can be intensively grazed for short periods outside the growing season has been shown to be effective. Seasonal use, again outside the growing period, should not have an adverse effect on meeting wildlife objectives. Yearlong rotational use may require exclusion fencing of the affected area to meet wildlife objectives. Fencing would add to the cost. Offsite range benefits can be accommodated however by allowing piping of water to a trough outside the fenced area.

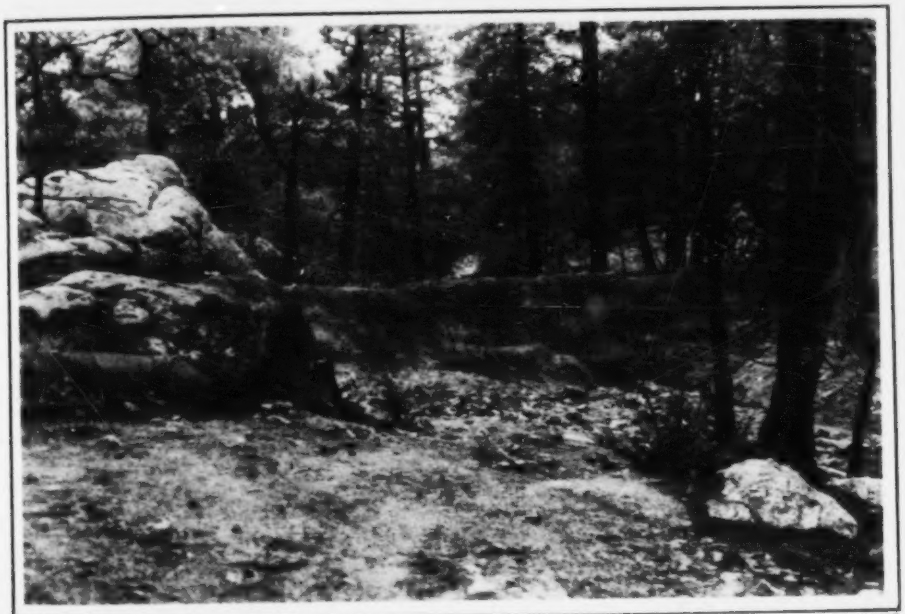

Figure 4. The structure is complete and blends in well with the natural surroundings.

LEGAL CONSIDERATION

Silt retention structures are exempt from appropriative water right laws. The Salt River Project, the holder of surface flow rights in our area, has been supportive of our projects. If the structures were designed as water impoundments, surface water rights would then be an issue.

There are two measures of the success of this volunteer oriented project. The first is meeting the resource objectives. The other is the volunteers perception of their involvement and contribution. You don't have a successful project without both types of success. Our project was successful in accomplishing resource objectives and at the same time gave our volunteers a sense of contribution and accomplishment of important resource objectives.

A considerable amount of logistical planning, coordination, commitment to the above philosophy, and effort is required. Our project was accomplished in one two day weekend and one three day weekend.

The partnership that evolved between the Forest Service, an off-road vehicle recreation group, a rancher, a wildlife conservation group, and several construction and service companies is unique and attests to the value of the project.

VOLUNTEER CONSIDERATIONS

The evolution of the partnership began with general solicitation for partners to achieve objectives of the National Recreation Strategy. Phil Auernheimer, President of ADRA, being familiar with similar past projects, volunteered his membership. Mr. Greg Bartzen of Verde Valley Pools and also an ADRA member volunteered to provide the survey, design, and engineering project supervision. The Arizona Wildlife Federation was contacted during the public involvement process and volunteered to contribute cash. The Arizona Desert Racing Association solicited the other donations, except the Yolo Ranch. The Yolo Ranch was contacted by the District as one of the grazing permittees involved.

We had planned to construct one poured concrete structure in 1988. The integration of the volunteers in the planning and the resultant suggestion of using the shotcrete technique and the level of support facilitated by the shotcrete process allowed, us to quadruple our accomplishment.

While it should never be planned for or advocated, the adverse weather conditions encountered on this project actually added to the sense of reward involved in the project accomplishment. The harsh conditions were endured, and problems were overcome through undaunted will and effort. Everyone involved, including the contractors, simply refused to allow the project to fail.

Table 1. The following listing displays the volunteer contribution in the Connell Mountain Wildlife Improvement Project:

Partners	Contributed	Value
Arizona Desert Racing Assn. (ADRA)	Skilled & unskilled labor; 252 man days @ $80.00/day average.	$20,160.00
	Paid for structural engineer review.	$ 290.00
Mr. Greg Bartzen Verde Valley Pools	Design and project engineering, 200 hours @$35.00/hour.	$ 7,000.00
Arizona Wildlife Federation	Shotcrete application (paid contractor).	$ 3,000.00
Everett Construction	Rebar.	$ 250.00
CECO Concrete Equipment Co.	Concrete pump.	$ 500.00
S.G. Steel	Rebar truck w/operator.	$ 2,000.00
SW Tractor	Compressor.	$ 400.00
McDonalds	Cooler and drinks.	$ 50.00
Arizona Rebar	Rebar and labor.	$ 1,500.00
Cohills Building Specialties	Concrete dye.	$ 225.00
Aaron's Sanitation	Portajohns.	$ 100.00
ADRA Membership	Transportation, food, and misc. tools and equipment.	$ 2,000.00
Yolo Ranch	2 days of backhoe and operator.	$ 500.00
Total Contribution		**$37,975.00**
Forest Service Matching Funds		$15,000.00
TOTAL		**$52,975.00**

ARIZONA'S STANDARD RAINWATER CATCHMENT

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Abstract

The standard rainwater catchment design as described circumvents chronic maintenance by; 1) incorporating metal studs rather than lumber 2) utilizing a chevron industrial membrane liner (rather than a PVC liner), and 3) adequate storage capacity.

It is visually acceptable and does not detract from wilderness values.

INTRODUCTION

The Arizona Game and Fish Department has been building water catchments for over 30 years. In earlier times, due primarily to constricted budgets, these water facilities tended to be hodge-podge affairs that all too often, fail to meet their objective of providing free water during drought periods. These older water catchments then become expensive due to the need to haul water to them each summer.

OPTIMUM DESIGN

The water catchment presented here (Figure 1), is the optimum design we have found to this point. Considerations that have lead us to this conclusion include:

A) Realistic Cost of Construction.
B) Minimum Cost of Maintenance.
C) Have Sufficient Water Storage Capacity.
D) Minimum Visual Impacts.
E) 50-Year Life Expectancy.

A) Realistic Cost of Construction

1. The cost of this water catchment is $ 14,000: $ 7,000 for materials $ 7,000 in labor costs.

B) Minimum Cost of Maintenance

Maintenance is minimized by the utilization of:

1. Fiberglass drinking troughs rather than concrete or metal.
2. Screwing all metal work together rather than nailing metal to lumber, where corrosion and time result in the nail losing its hold, and subsequent wind damage.
3. Utilizing an anchored, all-metal apron, rather than an asphalt or fabric apron susceptible to wind damage.
4. Placement of the storage reservoir under the watershed rather than standing alone, exposed.
5. Selection of Chevron Industrial Membrane for the tank liner, rather than a poly vinyl chloride bag liner. The Chevron Industrial Membrane has shown great potential and we expect it to seal the tank for the life of the development. Currently, our PVC bags last 10 years on the average.

C) Sufficient Water Storage Capacity

Selection of a storage reservoir of 17,000 gallons or greater. It is our best estimate that half to two-thirds of the available water is utilized by the target species. Our standard reservoir in the desert is 17,000 gallons. Arizona rarely achieves deer densities of $3/mi^2$ in the desert, therefore, we have found that catchments of 10,000 gallons or more rarely need water hauled to them. Provided, however, that apron collection surface area is adequate to fill them annually.

D) **Minimum Visual Impacts**

Minimum impact to land visual qualities is achieved by installation at or near ground level and camouflage painting.

E) **50-Year Life Expectancy**

Our objective to build a 50 year development should be attainable through selection of materials as noted and minimizing contact between the galvanized steel and the ground.

OTHER CONSIDERATIONS

The major drawback of this design is the requisite vehicle access. Thus it has limited value for such species as bighorn sheep. (Where vehicle access is impractical, Arizona utilizes fiberglass cylinders or improves natural rock tinajas.)

Site selection is very important when this design is employed. Soils in particular are much more workable if they contain a minimum of trees or outcroppings. Slope requirement needs are ideally 5% ranging from 2.5% to 10%. Whenever possible, avoid sites with a pitch perpendicular to the direction of the collection apron. This will result in reduced labor costs and a more stable system.

After selecting the site and calculating the size of the water developement the following procedures are followed:

A) Lay-out the boundaries and using a transit shoot several grades to position the storage tank to the collection apron and the drinker trough.
B) Excavate the tank hole, level the bottom of the hole, assemble the tank, seal the tank, assemble the roof section, apron, plumbing, prime and paint.
C) Fence the development if needed.

The following materials are required for a 9 inch rainfall area with a 17,000 gallon storage requirement.

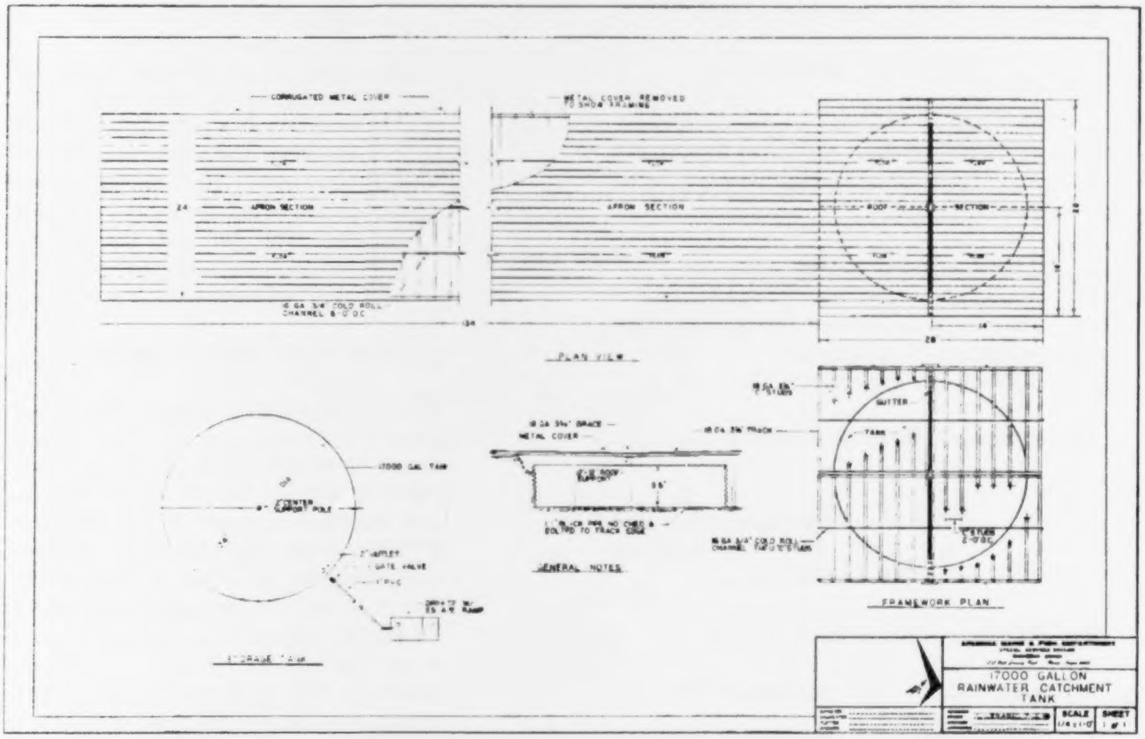
CORRUGATED METAL COVER
METAL COVER REMOVED TO SHOW FRAMING
APRON SECTION
APRON SECTION
ROOF SECTION
24
16 GA 3/4" COLD ROLL CHANNEL 6'-0" OC
134
28
14
PLAN VIEW
GUTTER
TANK
18 GA 3/4" BRACE
METAL COVER
18 GA 3/4" TRACK
17000 GAL TANK
CENTER SUPPORT POLE
2" GATE VALVE
1" PVC
GENERAL NOTES
FRAMEWORK PLAN
STORAGE TANK
17000 GALLON RAINWATER CATCHMENT TANK
SCALE
SHEET

Figure 1. 1700 Gallon Rainwater Catchment.

STANDARD CATCHMENT MATERIALS LIST

I. TANK/PLUMBING COMPONENTS

Quantity	Description
8	Tank Ring Sections - Top & Bottom w/Bolts
3 Rolls	Roofing Felt
24	Sheets Flat Tin 3' x 10', 7 Mil.
1 Roll	Hardware Cloth
1	Large Drinker 6'
½ Roll	Polyester Cloth
1	Center Pole 8' & Plate
12	5 Gal. Regular Chevron Industrial Membrane
2	5 Gal. Trowel Grade Chevron Industrial Membrane
7 Gal.	Catalyst
1	5 Gal. Bonding Agent
28 Bags	Cement
1	Float Valve, Ball, Rod Assembly
1	6' Step Ladder
8	Gloves - Chevron Industrial Membrane
12	Mixed Brushes for Chevron Industrial Membrane
3	Rubber Boots
4	Roofing Brushes
1	1" Gate Valve
6	Pipe Fittings - Nipple, Union, Elbow
1	Rain Gauge
1	Chevron Industrial Membrane Mixing Wand
1	24" Fiberglass Float Chamber

II. APRON/ROOF COMPONENTS

112 Sheets	Corrugated Tin 14' x 26"
50	C Studs 24' Long
10	Track 20' Long
16	Track 14' Long
24	C Studs 14' Long
20	Channel 20' Long
4,000	Hex Head Screws 12 ga. self tapping
3 Gal.	Green Paint
13 Gal.	Buff Brown Paint
3 Gal.	Dark Brown Paint
4	Paint Roller Covers
2,000	Framing Screws 6 ga. self tapping
4	21' - 1¼ Black Pipe
6	21' - 1" Galv. Pipe
2	Rakes
2	Shovels
2	Brooms
6	4' Pole Handles
4	Roller Frames

Quantity	Description
100	Bolts, Nuts, Washers
5 Gal.	Paint Thinner

III. FENCING COMPONENTS

2 Rolls	Barbed Wire
2 Rolls	Smooth Wire
140	Fence Stays - 1 Box Clips
12	Signs
67	Tee Posts
6	Corner Braces

WATER DEVELOPMENT PLANNING DATA

I. Water Development Objectives

A. Stabilize an existing wildlife population (mitigating other impacts to the habitat).
B. Increase an existing wildlife population.
C. Facilitate the success of a transplant program.
D. To make more effective use of available forage by manipulating population density.

II. Sonoran Desert Open Water Evaporation Rate = .5"/day

A. Drought up to 4 months (120 days).
B. 120 days x .5" = 60" vertical evaporation.
C. 5 feet depth required for tinaja to be perennial without considering animal use (Brown 1983).

III. Utilization

A. Deer/bighorn average 1.5 gallons per day on those days over 100° F (Hervert 1985).
B. Days in excess of 100° F average 100/year.
C. 150 gallons/ungulate/summer stress period is the management objective.
D. Deer/bighorn radius from water 3 miles during summer stress (Hervert 1985).
E. 28.26 sections of serviceable habitat/water source.
F. Assume density in Sonoran Desert is 3 deer/section.
G. 3 deer/section @ 28.26 section = 84.78 deer/water.
H. 84.78 deer @ 150 gallons/deer = 12,717 gallons storage requirement.
I. Item 3.h. assumes a static population to double the population of deer water capacity needs to expand to 25,434 gallons.
J. Storage need data not considering all other wildlife use of water (nontarget species probably use 50% of the water) (Elder 1956).

IV. Design Consideration

A. Cost
  1. Sectional steel catchments are $ 14,000/25,000 gallons ($0.56/gallon).
  2. Sectional steel design required 5 year interval vehicle access for maintenance.
  3. Fiberglass cylinder design costs $5,500/4,300 gallons ($1.28/gallon).
  4. Fiberglass cylinders require 5 year interval helicopter, foot, or horse access for maintenance.
  5. Tinajas cost $7,500/7,500 gallons ($1.00/gallon)
  6. Tinajas have little or no maintenance requirement.

V. Access

A. Must have vehicle access for sectional steel design.
B. Fiberglass cylinder projects generally require helicopter access.
C. Tinajas require helicopter or foot access.

VI. Labor

A. Tinajas are labor intensive approximately 1,000 man hours/project.
B. Sectional steel are moderate labor intensive at 320 man hours/project.
C. Fiberglass cylinders are least labor intensive at 40 man hours/project.

VII. Visual Considerations

A. Tinajas least obtrusive without shade.
B. Fiberglass cylinders and tinaja with shade are probably equivalent.
C. Sectional steel design is most obvious (with vehicle access trail). However, when painted, sectional steel designs have been permitted and constructed on BLM WSA's.
D. Shades have been allowed on both USFW and BLM WSA's to cut down evaporation losses on tinajas.

VIII. Evaporation Considerations

A. Is tinaja protected naturally? (Cliffs, overhangs, etc.)
B. How predictable is runoff?
C. Sectional steel design loses 5.8 gallons/day at the trough.
D. Fiberglass cylinder design loses 2.9 gallons/day at the trough.
E. A tinaja 7 feet deep with 10,000 gallon capacity loses 59.5 gallons/day. (In 168 days the tinaja will go dry. Conversely a 5,000 gallon fiberglass cylinder project will take about 10 years to go dry due to evaporation.)
F. Water quality is highest where evaporation is minimized. Sunlight obstruction reduces algae growth an concentration of salts and heavy metals.

IX. Fencing

A. Only to be used where burros or livestock threaten the water supply.
B. Fences greatly impede bighorn use and acceptance of new waters.
C. Preferred fence for bighorn sheep 200 feet on the side, 3 rail pipe fence with Rail #1 20" above ground, Rail #2 17" above Rail #1, Rail #3 7" above Rail #2.
D. Whenever possible it is preferred to habituate bighorn to the water development prior to fencing.
E. Attempt to work gaps into bighorn fence using natural bluffs, rock outcrops, etc., as movement corridors.
F. Bighorn do not negotiate wire fences with any degree of success.
G. Painting of pipe rail fences is unnecessary as oxidation blends the fence well with landscape.
H. For deer a 4 strand wildlife fence (smooth top and bottom) to BLM specs 150 feet on a side is the preferred fence.

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IDENTIFICATION AND CONSTRUCTION OF SLICKROCK WILDLIFE WATER DEVELOPMENTS IN SOUTHERN NEVADA BY NEVADA DEPARTMENT OF WILDLIFE

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Abstract

The Nevada Department of Wildlife has constructed wildlife water developments for desert bighorn sheep (Ovis canadensis nelsoni) in southern Nevada since 1985, which utilize exposed rock slabs, or slickrocks, as precipitation collection surfaces. Sites are evaluated for collection capability, dam size and location, tank pad size, storage capacity required, site security, and attractiveness to bighorn sheep. Materials and manpower are flown to each site by helicopter. The Fraternity of the Desert Bighorn provides volunteer labor and the benefit of practical experience. The results are reliable water sources for all wildlife which permit range and population expansion for the desert bighorn.

INTRODUCTION

The desert bighorn sheep (Ovis canadensis nelsoni) is well adapted for survival in the arid mountains of the southwestern United States. During recent history, encroachment by man and his livestock has dramatically reduced the numbers and ranges of the desert bighorn.

Currently, efforts are being made in Nevada to re-establish bighorns in habitat which remains suitable. Often these habitats have been altered or are lacking certain key elements. Free water is often the limiting factor, due to humans usurping natural waters for themselves or livestock. To mitigate these losses appropriate state and federal agencies have become involved in wildlife water development programs. Within the southern 1/3 of Nevada, large capacity water developments are constructed primarily for the benefit of desert bighorn sheep, but are available to all wildlife.

The Nevada Department of Wildlife has attempted to locate water developments in bighorn habitats where rock slabs may be used as precipitation collection surfaces. The "slickrock" surface provides several benefits: 1) It is cost-free, 2) It requires no maintenance, and 3) A large area can be utilized to collect runoff water, providing more water for storage.

SITE IDENTIFICATION

Nevada Department of Wildlife (NDOW) biologists consider the effective range of desert bighorn sheep to be two miles (3.2 km) from a water source during the critical summer period. Accounting for terrain and elevation, water developments should be separated by no more than four miles (6.4 km) and no less than one mile (1.6 km) to completely utilize bighorn habitat. Currently, water developments are being located in pairs or clusters to provide core summer ranges. Should habitat and population growth warrant conversion of perimeter areas to summer use, sites are noted for possible later development.

Forage, terrain, and conflicting uses are evaluated to determine the best habitat within each mountain range to locate water developments. The inter-relationships of these components are considered during the site location process. Given the necessary spacing, habitat limitations, and availability of the slickrock surface, and the security of the sheep should be kept in mind. This involves locating the water source in an area where good visibility is afforded to sheep from trails, possible bedding areas, and likely observation points.

The water source is often located in areas accessible only to wildlife. In some instances, however, feral and domestic livestock must be restricted. A water source, or drinker, which prevents the insertion of a large muzzle is favored. Fencing is a costly last resort which may inhibit wildlife use.

To reduce intrusions by humans and the chance of vandalism, water developments are usually located at least one quarter mile (.4 km) from the nearest road or access point. This has added to the cost of each project because a helicopter is required to move materials and workers to the site. However, the developments may now be located in more suitable and secure areas for the sheep.

Each development is constructed to fit into the environment as unobtrusively as possible. Rock native to the site is used to face the dam and construct the drinker. Pipelines are buried, covered, or painted.

The standard tank used is eight feet high, seven and one half feet in diameter, and has a capacity of 2300 gallons. It is sometimes necessary to locate the tank away from natural features which might hide the bulk and outline. Painting the tanks is done on all developments, but is critical in these instances. A covering of exterior flat latex paint is usually adequate. While dark browns or grays have worked well on past developments, these shades now serve as a base, while light to mid-tone browns and grays are used to further break the outline by patterning with the predominant site features (usually rock ledges and walls.)

The slickrock surface itself must be able to collect a sufficient amount of rainfall to fill the tanks at each site. A 40 foot by 70 foot surface adequately sheds water in most cases to maintain a 4600 gallon capacity over the course of a year. Allowing for southern Nevada's prolonged dry periods, NDOW attempts to use the largest area possible to maximize collection of even the lightest rains. In some cases, the collection area can be expanded easily by constructing curbing which funnels water toward the dam. Surfaces of wash bottoms which collect silt and sand are selected against because this debris absorbs some of the water and may clog the filters. This reduces effectiveness and can require costly maintenance.

The dam is placed where the surface is most constricted to allow construction of the smallest dam possible. Dams near steep dropoffs are generally avoided for safety considerations.

Tank location considerations may require the dam to be constructed above the preferred location to attain adequate drop supply pipe from the bottom of the dam to the top of the tank. This slope should not be less than 5%. Insufficient slope prevents the maximum possible siphoning of water at the dam, causing water to build up and overflow the dam.

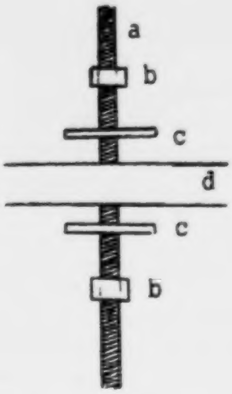
Placement of the water storage tanks is second in importance only to the slickrock surface itself. For the "standard" NDOW two tank, 4600 gallon storage capacity segment of the development, an 18 foot by 9 foot, level surface must be constructed. The tank pad should be constructed considering the 18 ton load of the tanks. Even a narrow pad which necessitates using a single 3000 gallon tank must withstand a 12 ton load. Pads constructed on steep slopes may require added support and/or concrete.

Total storage capacity desired is vital during the initial site identification process. NDOW estimates a minimum requirement of one gallon of water per sheep per day during the approximately 100 days of critical summer period. The current standard development stores a maximum of 4600 gallons and would support 40 to 46 sheep during the summer within the two mile effective radius. This translates to 3.2 bighorns per square mile. Beginning in 1989, all NDOW bighorn sheep water developments will have plumbing assembled to easily allow a third tank to be added if wildlife utilization warrants. In such cases, the third tank is filled from the overflow of the original tanks.

BASIC CONSTRUCTION CONSIDERATIONS

Although considerable effort goes into dam construction, it is not required to be watertight. A dam serves merely to retard the flow of runoff so that it may be collected and transported to storage tanks. Some seepage will occur under the dam eventually. It should be kept to a minimum through routine maintenance.

The width of the dam tends to be 12 inches. Lengths have extended 20 feet, but are more often six to ten feet. Height averages four feet, which allows intense runoff to overflow the dam, often scouring out any debris in the process. The dam is formed with one half inch CDX plywood sheets held apart with nuts and large



Allthread Assembly

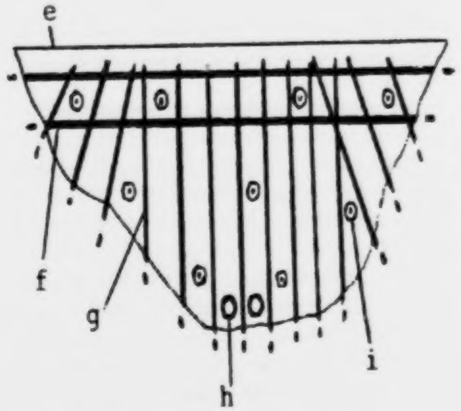
a. ¼" x 18" Allthread
b. ¼" Hex-head Nut
c. ¼" x 1½" Fender Washer
d. ½" CDX Plywood

Figure 1. Allthread Assembly.

washers on one quarter in all-thread (Figure 1.) One half inch and one inch rebar rods are used for reinforcement (Figure 2.) An average dam requires 50 bags of pre-mix concrete, with 50 gallons of water supplied.

A pair of two inch diameter galvanized pipes extend through the bottom of the dam (Figure 3.) The upper end of each pipe is fitted with a water well filter device called a Johnson screen (Johnson Division of Weelebler-Brator Technologies, St. Paul, MN.) Each screen is two feet long, four inches in diameter, and can filter up to 30 gallons per minute. The lower end of the galvanized pipe is attached to a two inch diameter poly-pipe which feeds the storage tank.

Both two inch and one inch diameter poly-pipes used on NDOW projects are Phillips Petroleum's Driscopipe 8600 series (Richardson, TX.) This pipe is produced with ultraviolet light inhibitors which reduce the effects of weathering.

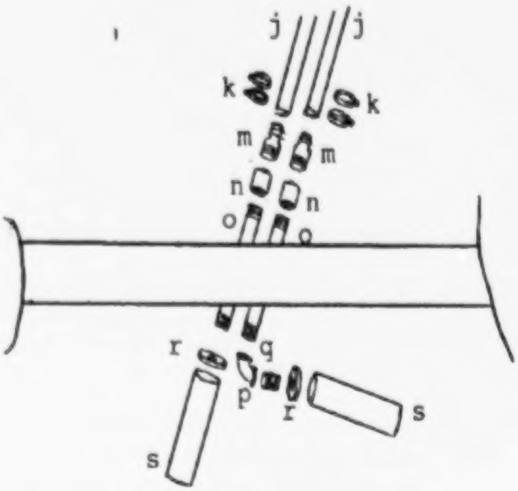


Dam Materials

e. ½" x 4' x 8'
CDX Plywood
f. 1" Rebar
g. ½" Rebar
h. 2" Galvanized Pipe
i. Allthread Assembly

Figure 2. Dam Design and Materials

FIGURE 3



j. 2" Driscopipe

k. Size 32 to 40 Hose Clamp

m. 2" Galvanized Barb Fitting

n. 2" Galv. Coupler

o. 2" Galv. 3 ft. Pipe

p. 2" Galv 90° Elbow

q. 2" Galv. Nipple

r. Galv. 4" to 2" Reducer Bushing

s. Johnson Screen

Figure 3. Outlet pipe and Johnson Screen.

It is manufactured for industrial uses, but its durability and resistance to cracking makes it well suited for use on wildlife water developments. Driscopipe 8600 has proven reliable to date in exposed and covered applications. NDOW attempts to protect all components as well as possible, such that pipe is buried, covered, insulated, or painted where needed.

During maximum runoff, there is approximately one gallon of water per 74 inches of two inch diameter pipe. This eight pound weight is travelling down a slope of 4% to 90% (in extreme cases) sometimes causing considerable vibration. Plumber's tape and masonry anchors have been used in the past to secure pipe to rock walls. However, on one impending project, five inch diameter Figure 89 type pipehangers will be used with masonry anchors and all-thread to secure hanging pipe. Support should be considered where inflow lines are attached to the tank, so as not to exert undue stress on the tank walls.

As long as the system holds water, the one inch metal and Driscopipe from the tanks to the floatbox and drinker are susceptible to freezing and thawing damage. This component is always insulated, then buried or covered.

Fiberglass tanks have been utilized in the past on big game water developments. NDOW currently purchases up-right polyethylene tanks (Rotational Molding, Gardena, CA.) Both cross-linked and linear low density constructions utilize Marlex resins produced by Phillips Petroleum. These tanks have proven strong and durable under the extremes of Nevada weather. The three tank sizes used are 1600 gallon (six foot height), 2300 gallon (eight foot height), and 3000 gallon (ten foot height.) Each tank has a diameter of approximately seven and one half feet. Size selection depends on storage capacity required, pad size limitations, and visual problems. Limited pad space generally dictates the use of one 3000 gallon tank. Where lower tank profiles are required, three 1600 gallon tanks are used.

Tank holes are pre-drilled and pipe is cut (generously) prior to transport to the staging areas. Holes for attaching overflow lines are cut just above inflow holes, and the equalizing line between tanks below the overflow hole.

Inflow pipes So the tanks are attached with galvanized fittings for strength and durability (Figure 4.) Each tank pair is linked by an equalizing line. This allows excess water to flow between tanks before the water level rises to the overflows, thus filling a tank with a failed inflow system.

Tanks currently in use are manufactured with moldings on the top at opposite sides to facilitate tying the tanks down with wire rope. This precaution need not be an engineering marvel, as it must only prevent movement of the tanks until water provides sufficient ballast.

Outflow lines are of one inch diameter, with both tanks linked by a manifold which feeds the drinker through a single line (Figure 5.) The upper sections of each manifold utilize metal components. Stainless steel tank adapters provide the outlet connection. Past use of a PVC adapter and nipple resulted in a cracked nipple when the tank settled at one development. The all metal system is stronger and permits any flexing to occur at the tank wall, which is acceptable. The outflow consists of a gate valve, check valve, and then standard fittings which direct the manifold underground. The gate valve permits the flow from a tank to be shut off, making repairs easier. The check valve prevents the loss of all stored water if only one tank fails.

The single feed line runs from the manifold to the floatbox which regulates the flow to the drinker. In the past, the drinker has more often been a separate component made of native rock and cement. In 1989, all NDOW desert bighorn projects will have a one-piece floatbox-drinker (Figure 6.) This set-up requires fewer attachments, reducing the chance of failures. The floatbox-drinker is adapted to each site by surrounding the exposed portions with rock native to the site.

The last, but not least, consideration is how to get materials and manpower to the development site. Due to the preferred inaccessibility of bighorn sheep water developments, materials are most easily transported by helicopter. Landing pads are located at or near the site. A base, or staging area, is selected to provide the closest/best access to the site(s), while considering access to the base by truck. The flight path to and from the site should be anticipated concerning approaches, elevations, possible obstructions, unloading points, length of cables needed, and flight times. These points, type of flying, need for extra fuel, and anticipated weather are discussed in advance with the pilot.

Roughly eight to ten sling loads are required to move materials. NDOW has used a rough procedure to simplify the process. Nets (preferably four or five) are loaded prior to the first flight, which drops two or three people at the site to unhook and unload the nets. Then the slinging begins. After a net is emptied at the site it can be hooked onto the cable after a new load is taken off. The empty net is returned to the staging area for reloading. Three inch by six foot straps are used to haul rebar, pipe, water drums, and tanks. A strap can be looped through the pre-drilled holes in the tanks for easy slinging.

Materials are generally unloaded in two areas. Cement, water, rebar, generators, etc. are placed at the dam site. Unless the larger pipe can have an end easily pulled up a cliff, it is better to uncoil it by rolling it down from the dam. Tanks, floatbox-drinker, small pipe, etc. is placed at the tank site.

Workers may walk in to some locations. ATV's and horses may be used and travel is restricted to washes. These methods of travel often create an undesirable footpath to the development. More often than not, workers are transported by helicopter to the site. Although this can add significantly to the cost of a project, the crews arrive fresh and in a timely manner.

NDOW determines site suitability using these many factors. If the site proves feasible it is identified to the appropriate land management agency, prioritized, and tentatively scheduled for construction.

CONSTRUCTION

The Las Vegas-based Fraternity of the Desert Bighorn figures prominently in the construction of most bighorn water developments in southern Nevada. A core of these volunteers apply construction skills and other practical experience to each development. Sites are surveyed well in advance of construction by an NDOW biologist and Fraternity members to determine materials needed and to solve any problems. In several cases, Fraternity members have identified sites for NDOW developments.

Inflow, Equalizer, and Overflow Materials

a. 2" Driscopipe
    1. Inflow Line From Dam
    2. Equalizer Line Between Tanks
    3. Overflow Line
b. 2" Galvanized Barb Fitting
c. 2" (Size 32 to 40) Hose Clamp
d. 2" Conduit Nut
e. 2" Galvanized Coupler
f. 2" PVC Male Threaded x Barb Adapter
g. 2" Slip x Female Threaded Coupler
h. 2" 90° Female Threaded x Barb Adapter

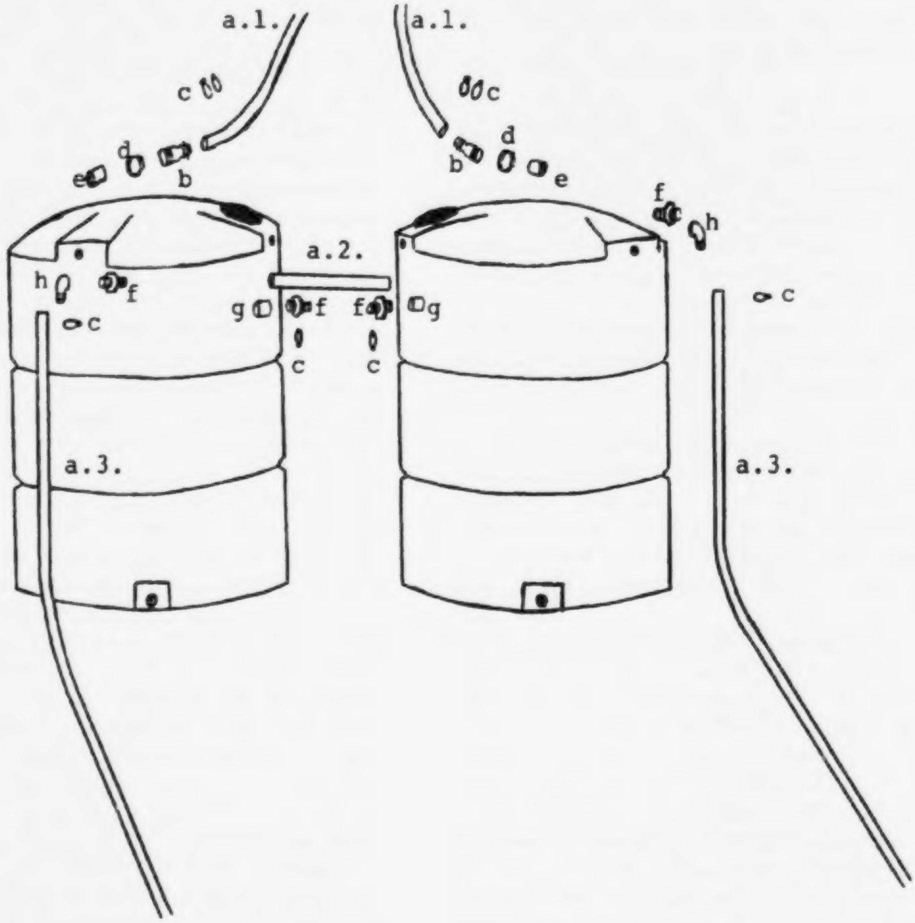


Figure 4. Inflow, Equalizer, and Overflow Materials.

Manifold Materials

a. Stainless Steel 1" Tank Adapter
b. 1" Galv. Nipple
c. 1" Brass Gate Valve
d. 1" Galv. Shoulderless Nipple
e. 1" Brass Check Valve
f. 1" Galv. 90° Elbow
g. 1" Galv. 6" Nipple
h. 1" Galv. Tee
i. 1" Galv. Barb Fitting
j. 1" (Size 20) Hose Clamp
k. 1" Driscopipe - 9 ft.
l. 1" Driscopipe - To Floatbox-Drinker
m. 1" Galv. Plug

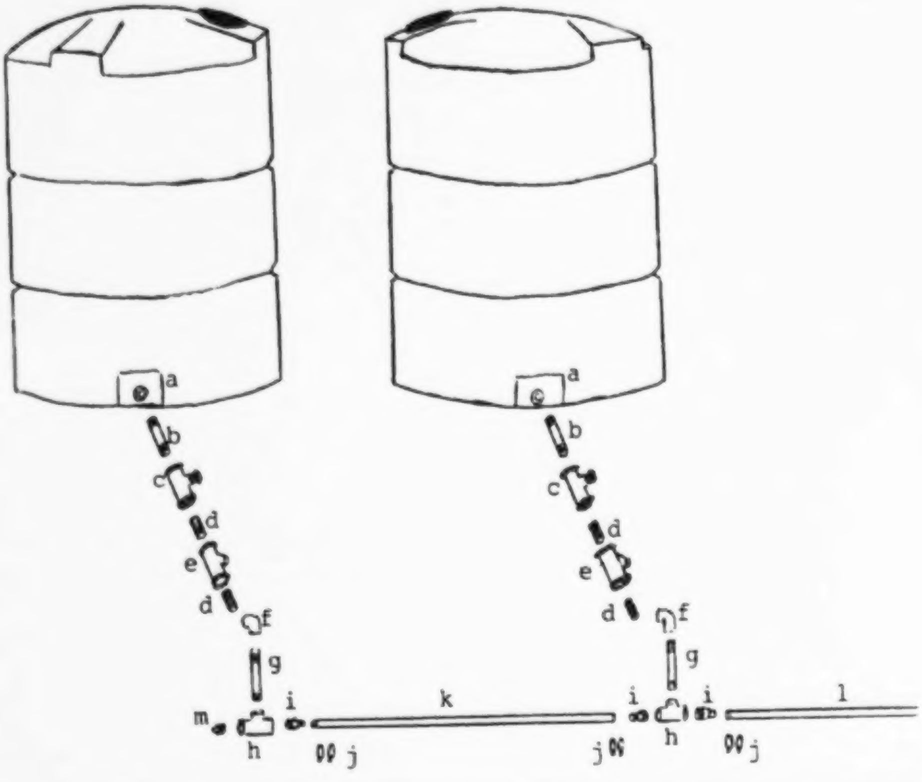


Figure 5. Manifold Materials.

During construction these volunteers need no supervision. Skilled workers gravitate to the dam work or plumbing the system. The remainder of the 30 to 50 person crew provides whatever other labor is needed. Upon completion, Fraternity members inspect the projects regularly.

The construction season for NDOW projects using volunteer labor extends from January through May. Few distractions persist (ie. hunting seasons and holidays) during this period. Cool weather allows heavy labor to be less taxing on individuals. Water developments are constructed on weekends for obvious reasons.

Single development construction allows the flexibility of slinging materials to the site early in the morning prior to the arrival of the volunteers. This saves on the helicopter costs by having the helicopter ferry to the area only once. If the project involves two or more sites, materials should be flown to the sites several days in advance. In these instances, it is preferable to construct the site with poor access first. In the event of high afternoon winds or helicopter difficulties, the crew has most of the day to walk out of the first site, or the easier walk out toward the end of the day at the second site.

Spare parts are supplied at each site, within reason. The majority of the extra fittings, pipe, water, etc. is kept at the base. Extra parts should be supplied to certain components to give workers some flexibility. An example is the supply of two inch galvanized elbows and nipples given to the dam crew. They allow the crew to angle the Johnson screens to fit the space behind the dam (Figure 3.) Several volunteers at each site are supplied with detailed diagrams of the development. Technical or local terms can be confusing to some. With this system parts can be referred to using a single term or reduced to a number (Figures 1 through 7.) Getting it right the first time is important whether parts needed are hiked up or flown up from the staging area. Flight time can cost up to $7 per minute.

Floatbox-Drinker Unit

a. Floatbox Compartment
b. Drinker
c. Float Assembly
d. Expanded Metal (Allows rodents,lizards, and birds adequate footing)
e. 1" Galvanized Barb Fitting
f. 1" (Size 20) Hose Clamp
g. 1" Driscopipe - From Tanks
h. Floatbox Lid

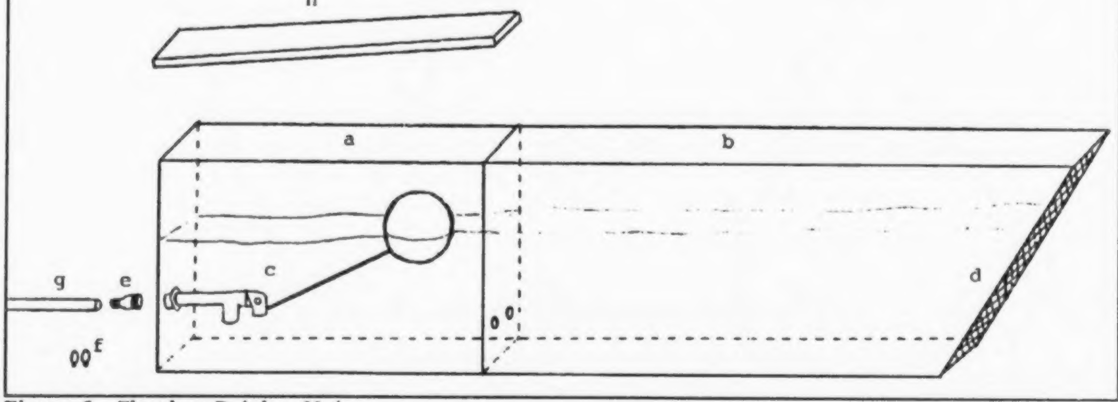


Figure 6. Floatbox-Drinker Unit.

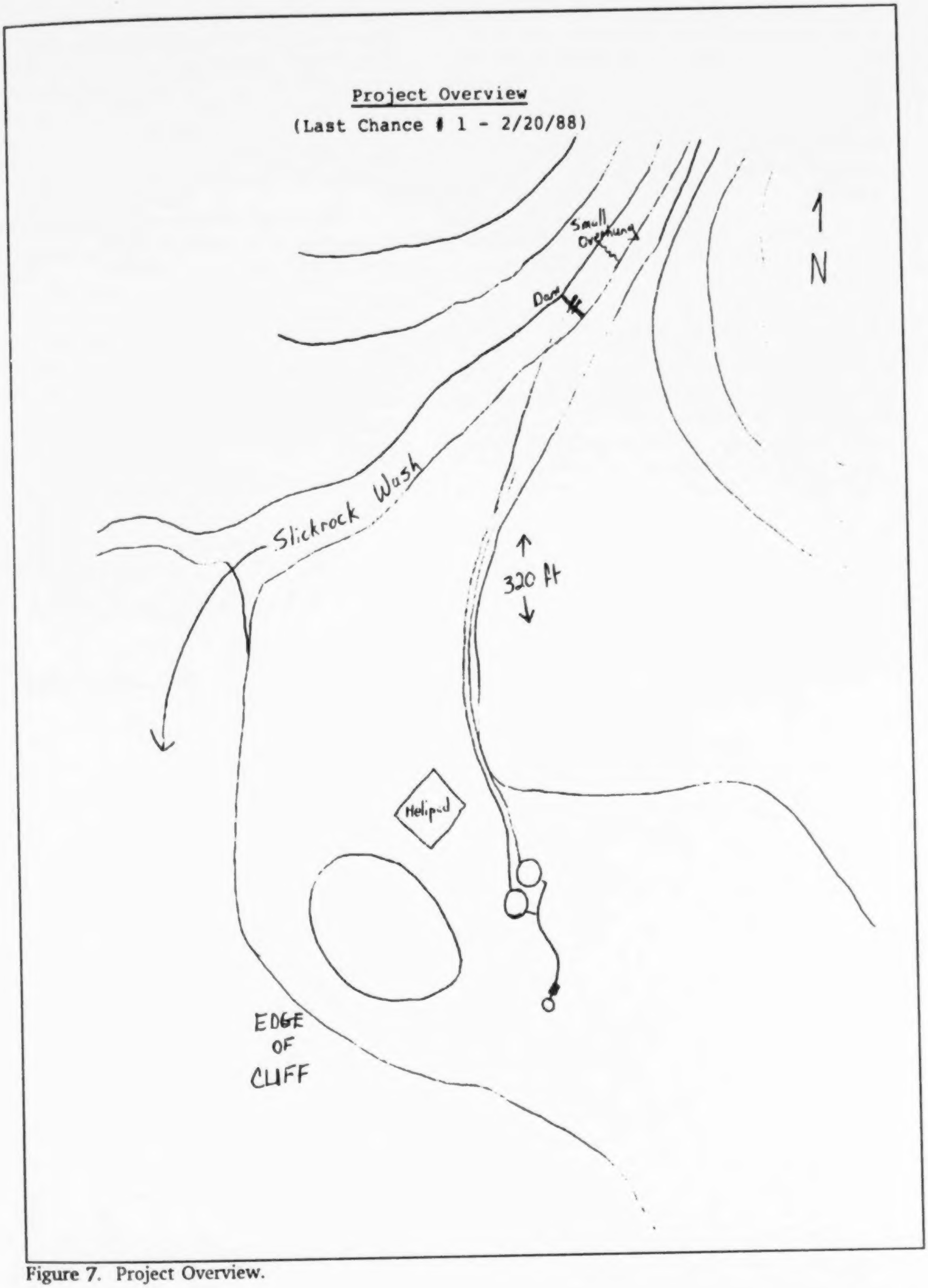

Project Overview
(Last Chance # 1 - 2/20/88)
Small Overhang
Dam
N
Slickrock Wash
320 ft
Helipad
EDGE OF CLIFF

Figure 7. Project Overview.

Following the paint and final touches, the crew leaves the site to await the first rains. Following this event the development is inspected. Emphasis is placed on checking the manifold and drinker components. Adjustments and repairs are made then or as soon as possible. Proper function of each development should be inspected at least in the spring and early summer annually.

Relative costs of construction of three NDOW bighorn sheep water developments are included in Table I.

CONCLUSION

Numerous considerations and trade-offs go into site selection and construction of Nevada Department of Wildlife desert bighorn sheep water developments. Slickrock surface limit the location of these developments somewhat. However, substantial benefits are derived the natural surfaces. Construction cost and effort are reduced and maintenance is minimal. Industrial quality components are used to provide durability and provide the longest possible life for each project. Design and components have evolved extensively and should continue to do so to provide a quality product.

Volunteer labor provided by the Fraternity of the Desert Bighorn has been essential to product evolution and affordability. It is hoped that this can continue.

Current bighorn population and range expansions depend on the continued co-operative efforts of federal, state, and private organizations. Wildlife water developments offer a direct, positive means to influence habitat of the desert bighorn.

TABLE 1

ESTIMATED COST OF LAST CHANCE WATER DEVELOPMENT - 2/88

	LC #1	LC #2	LC #3	TOTAL
Materials	$3,753.91	$3,782.39	$3,516.66	$11,052.96
Labor ($10.00/Hour)	$2,530.00	$1,530.00	$1,710.00	$ 5,770.00
Helicopter Costs Total	$1,470.00	$ 830.00	$1,680.00	$ 3,980.00
Fraternity Paid	$ 500.00	$ 300.00	$ 500.00	$ 1,300.00
Donated by Action Helicoper (to Fraternity)	$ 200.00	$ 200.00	$ 200.00	$ 600.00
NDOW Paid	$ 770.00	$ 330.00	$ 980.00	$ 2,080.00
ESTIMATED REAL COSTS	**$7,753.91**	**$6,142.39**	**$6.906.66**	**$20,802.96**
Savings by using the Fraternity (and Action's Donation)	$3,230.00 (41.7%)	$2,030.00 (33.0%)	$2,410.00 (34.9)	$ 7,670.00 (36.9%)
NDOW TOTAL COST	**$4,523.91**	**$4,112.39**	**$4,496.66**	**$13,132.96**

FENCING WILDLIFE WATER DEVELOPMENTS

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Abstract

Selective Exclusion Fencing to allow passage of mule deer (Odocoileus hemionus), antelope (Antilocapra americana) and desert bighorn sheep (Ovis canadensis spp.) but exclude horses (Equus caballus), cattle (Bos taurus), burros (Equus assinus) and domestic sheep (Ovis aries) is discussed. Fence specifications are described, emphasizing proven designs, but including identification of designs that are unsafe for wildlife.

Key Words: Selective Exclusion Fencing, Helvie Fence, BLM standard 4-wire fence, pipe fence-horses, wood rail fence-horses.

INTRODUCTION

Virtually all papers presented at this first Wildlife Water Symposium deal with some aspect of water development: from construction methods to the use of volunteer labor. This paper will deal with protecting those developments by fencing. Why fence? There are two basic reasons: first is to protect the investment, which usually runs from several hundred to several thousand dollars in materials, equipment, and man-time. The second is to protect the water from large, unwanted consumers. In western Nevada, wild horses and burros, cattle, and domestic sheep all qualify as unwanted consumers when water developments for wildlife are considered. Fencing to exclude domestic and feral animals is called Selective Exclusion Fencing, a term which first appears in the 1973 Desert Bighorn Council transactions (Cleary, 1973). This paper will center on Selective Exclusion Fencing to exclude unwanted species but allow access by mule deer, antelope, and desert bighorn sheep. Species not included are elk (Cervus canadensis), moose (Alces alces) or bison (Bison bison). This paper will cover fence designs that have been proven over time, some to be avoided, and experimental designs.

There are two reference documents which address fences at length. The first is BLM Manual Section 1741. It contains instructions, descriptions, and one page of line drawings of various fences. The fence shown under "Combination of cattle with burros and bighorn sheep" is dangerous to bighorns and should not be used: the adjacent drawing is a Helvie fence, which is discussed below. The U.S. Forest Service (Karsky, 1988) recently issued a major document called Fences. It contains much useful information on fence construction, with some specifications. It does not mention bighorn sheep. Neither of these documents specifically addresses fences to be placed around wildlife waters. The reader should bear in mind that fencing around waters is needfully more restrictive/stronger/etc., than fencing between forage areas.

FENCING CONSIDERATIONS AND DESIGNS

There are several criteria to be considered when developing water and protecting it with fencing: 1. environmental considerations, particularly concerning wilderness and Wilderness Study Areas; 2. fence construction problems and opportunities; 3. the nearest available water; 4. animals to be excluded; 5. animals to be allowed.

Environmental Considerations

The BLM in the Carson City district, with volunteer labor, has constructed two guzzlers for desert bighorn sheep in the past eighteen months in a BLM Wilderness Study Area (WSA). A three-rail steel pipe fence was constructed around the first guzzler. Since the fence was built in a WSA and was of galvanized steel, it had to be painted a dull gray color using zinc oxide primer. All materials had to be flown in by helicopter, but we were allowed to walk in a small caterpillar tractor with backhoe. The key element here is that the agency wilderness specialist or recreation planners must coordinate well in advance of construction. Also in BLM, several wilderness groups are contacted for their comments prior to each of these developments.

Between construction of the first and second guzzler, which are less than two air miles apart, interpretations of the ground rules changed for range improvements (including guzzlers) in WSA's. The second site used a wood pole and rail fence requiring no post holes. This fence and the guzzler it protects can be removed with little difficulty if it is deemed advisable in the future.

Construction

If the soil is very rocky, shovels, picks, and prybars, and even power post-hole diggers may not be adequate. We used a backhoe to dig every hole for the steel pipe fence, and then backfilled each by hand. If the site is sandy or has small rocks, anything from shovels and post pounders to a power auger will work.

The work force must be considered as well. An agency force account crew or contractor are preferred. Problems may arise if young volunteers are used. We constructed one fence around the public portion of a heavily used meadow with help from two teenager volunteers. Neither was strong enough to wield a shovel. If young volunteers are used, you may have difficulty in completing the job in the time allotted, simply because they are not capable of using the equipment. They also require constant supervision because most of them have never done this type of work before. Adult volunteers have worked very well for us on four big game guzzler and fence jobs. Communications is a key element: explain the concept, explain specific tasks; make sure the crew understands what is required and what the specifications are.

Nearest Available Water

A steel pipe fence was built around one guzzler because it lies adjacent to a major horse trail to water, and that water is a mile and a half up-canyon from the guzzler. Thus, if the wildlife water to be constructed is the only water source for several square miles, as it was in this case, the wildlife water must be well protected. On the other hand, if a guzzler is being built in an area of suitable habitat for a particular wildlife species, and that habitat is surrounded by habitat of lesser quality but which is well watered, the fence will not have to be nearly as strong as a steel pipe fence. We built such a guzzler in the Sand Hills north of Reno which serves mule deer, antelope, and chukar with only a four strand barbed wire fence protecting the source.

Animals to be Excluded or Allowed

All of the big game species we are dealing with are roughly three feet tall at the shoulder and have a brisket depth of 16-18 inches. The horn and antlers sizes are different, of course. The major probelm was the differences in size between the animals to be excluded: horses are much taller than burros and cows, which are much taller than domestic sheep. The worst problems, district wide, are with horses and cows.

Helvie (1971), Refuge Manager of the U.S. Fish and Wildlife Service Desert National Wildlife Range (DWNR) north of Las Vegas tried several experimental fences using penned desert bighorns. He tried eight different configurations of barbed wire and five types of rail fences. Based on how well these allowed desert bighorns to pass through and how well they excluded cattle, he recommended just two, as follows: for wire fences, posts were ten feet apart, and wire spacing, as measured from the ground, was 20", 35" and 39". The top two wires were only four inches apart because it was found not only at DNWR but along highway fences in Arizona as well that a larger spacing- 6 or 8 inches allowed bighorns to put their heads and horns through, but not their bodies. When they tried to back out, they could not, and they became entangled (Welsh, 1971). The 20 inch gap from ground to the first wire allowed bighorns to go under the fence; the 15 inches above it allowed bighorns to go through the fence. (Some bighorns do neither, but jump, instead (Campbell, personal communication)). The bottom wire on this (and all other wire fences recommended) should be smooth. Helvie also noted that the bottom wire should be no less than 20 inches above ground, the bottom two wires no less than 15 inches apart, and the top two wires no more than four inches apart. The rail fence Helvie recommendedhad uprights ten feet apart. Rails were two-inch pipe or four-inch wood rails, as rams broke smaller wood rails. Lower edges of the rails should be 20, 38, and 44 inches above ground. Agencies that use the Helvie fence include the BLM, California Department of Fish

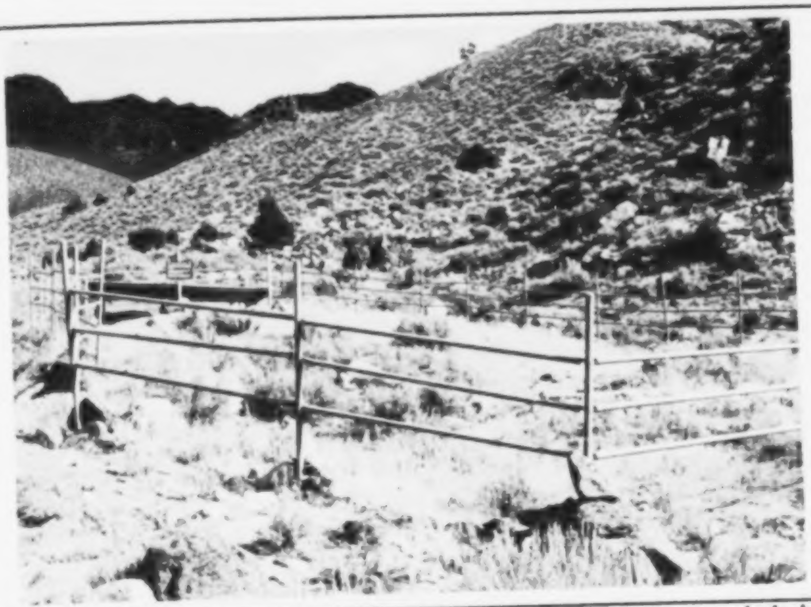

Figure 1. Three rail steel pipe fence around desert bighorn guzzler, built to exclude horses. Rails are 32, 46, and 60 inches above ground. Note grass inside the fence and lack of it outside.

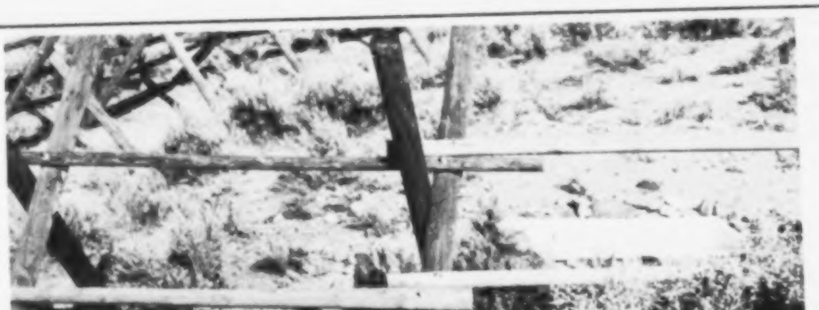

Figure 2. Pole and rail fence to exclude horses from a desert bighorn sheep guzzler. Poles are 7 feet apart, rails are 28, 45, and 72 inches up the pole from ground level. Pole feet are spread 6 feet apart.

and Game (Weaver, pers. comm. 1988) National Park Service (Douglas, pers. comm. 1988), Arizona Game and Fish Department (deVos, pers. comm.) and New Mexico Game and Fish Department (Sandoval, pers. comm.). The Arizona Game and Fish Department uses the basic configuration but adds two strands of barbed wire on top.

The Helvie fence has proved successful for excluding cattle and burros. We like the rail idea, and opted to use a three rail fence, made of steel pipe, around the first desert bighorn guzzler we constructed in the WSA (Figure 1). Horses are a major problem, as noted above. Cattle use the area, but are trailed up the canyon by riders. We used a spacing of 32, 46, and 60 inches from the ground. As noted above, this site was extremely rocky, as we placed the guzzler next to the best bighorn escape cover we could find. Each post hole (eight-foot centers) was dug with a backhoe and then refilled by hand. After 14 months, the guzzler is more than half full of water, and the fence is intact and functioning. We used 8 foot x 2 3/8 inch outside diameter Schedule 40 galvanized steel pipe for posts, and 8 foot x 1 7/8 inch o.d. BSS Schedule 30 pipe for the rails, plus suitable steel caps, rail ends, and brace bands. We also had short (4-6 inch) pieces of 1 ½ inch angle iron welded to the bottoms of the posts, so they could not be pulled out easily. We recommend the use of deeper rail ends. This fence cost $5.85 per running foot for parts alone. I have not figured in labor costs nor helicopter transportation, since the fence was just one aspect of the project. This fence is the first of its kind in terms of rail spacing. To date it has worked very well to exclude horses and cattle, and should be maintenance free for several years.

A second design we are trying around a desert bighorn guzzler is a wood pole and rail fence (Fig 2). Poles are 8 ½ feet long, on 7 foot centers. Rails are 16 feet long, and are 3½-4½ inch diameter. Rail spacing along each pole is 28, 45, and 72 inches from the bottom of the pole. The poles are set tepee fashion and are bolted together at about 5 ½ feet from the bottom end. The bottoms of the poles are 6 feet apart and are held at that length by smooth wire. The configuration allows bighorn (and deer) to pass through or under. Cattle and horses are excluded. This fence has not been in place long enough for us to evaluate. The thing we have not done and plan to do is to cut off the tops of the poles just above the top rail. It will make for a much neater and more aesthetic appearance. The cost for materials, including poles, rails, smooth wire, nuts, washers, and threaded stock is $3.85 per running foot.

BLM fencing has evolved over the years from a standard livestock fence (in Nevada a legal fence is four strands of barbed wire, spaced 12, 24, 36, and 48 inches from the ground) to what it is today. The old 48 inch height was not a major obstacle to deer in many places, but did pose major obstacles if there was snow on the ground or if the deer had to jump uphill over it because they couldn't get through it. When deer jump, all four feet are forward. If they cleared the 48 inch wire with all four feet, fine: if not their rear legs slid between the top and third wire which could result in a tragic loss. We had major fence problems in the Elko (northeast Nevada) and Carson City areas in the 1950's and 1960's. Since then the top wire was dropped from 48 inches to 42 inches and has made a tremendous difference. The bottom wire was raised from 12 inches to 16 to 18 inches, which allowed the deer to go under. A smooth bottom wire helped. Our current BLM fence in Nevada also is specified as follows: posts are 10 feet to one rod (16 ½ feet) apart, wires are spaced 16(to 18), 22, 30, and 42 inches above ground. The only real problems we have had at Carson City with these specifications is that deer have run into the fences at night. We fenced a two-acre meadow in deer winter range and deer broke the wires twice at both ends of the meadow. We flagged the wires with surveyor's tape and have had no damage since.

The basic configuration may be modified: we constructed a big game guzzler for both deer and antelope in an area that has adequate water elsewhere for horses and cattle. We raised the top wire to 46 inches, to exclude horses. This unit has been in place for two years, and has not been forced by either horses or cattle.

Another fence design we are trying is a single vertical wood pole and two wood-rail fence (Fig. 3) to repel horses in deer country. This fence was constructed early this year. It has not been breached, but deer are using the spring and riparian area inside it. There is good fenceline contrast between the interior and outside the fence. This is one of those areas where there is adequate water nearby for horses, so no additional poles or rails were used. Poles are on

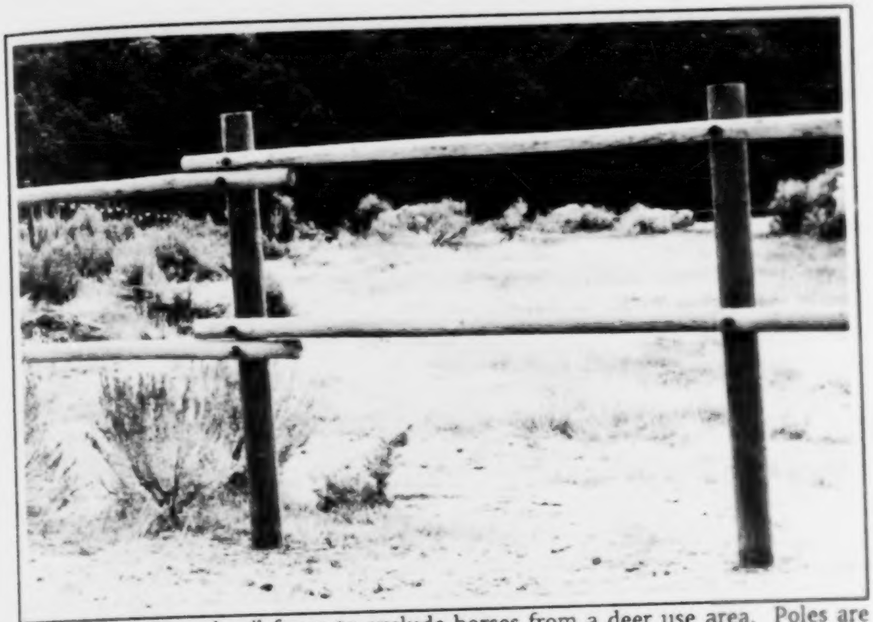

Figure 3. Pole and rail fence to exclude horses from a deer use area. Poles are on 7 foot centers, 16 foot rails are 30 and 60 inches above ground.

7 foot centers and rails are 16 feet long. Rail spacing is 30 and 60 inches above ground, measured to rail bottom.

We use the same specifications for antelope and have not had any problems to date--they can get under this fence design. We have not tried antelope passes (which are miniature cattle guards) as our antelope populations are not high enough in any given area to warrant the extra cost involved. We don't worry about them jumping, as they are very capable of it and have done so in Nevada (Armentrout, pers. comm. , 1988). The accommodations we make for antelope around waters is to make the fence at least one acre in size, as antelope seldom use fenced areas smaller than that (Yoakum, per, comm.m 1985).

There are more than 120 guzzlers of various styles and targeted for various species, in the Carson City district alone. The vast majority, over 100, were constructed for small game and nongame use. Most are in areas not frequented by big game. We do, however, have cattle to contend with, not from the water consumption standpoint, but from the fact that steel uprights are very good places to rub and scratch on. We have tried several designs, varying from the standard BLM four-wire fence just described, to single pole corners, to our current design. We use the uprights themselves as posts. The barbed wire is anchored by drilling two 1/4 inch holes on either side of the wire and using a U-shaped fence staple as a holder. The ends of the staple straddle the wire, fit into the 1/4 inch holes, the staple is pushed in as far as it will go, and then the ends are bent flat on the back side of the steel upright. For the front of the apron, where the rain gutter collects water, we anchor two 6 inch to 8 inch diameter wood posts next to the steel uprights. This gets the wire away from the gutter but still protects it. This design works well and we have had no problems with it. About 35 per cent of our upland game guzzlers are protected this way; the rest have a standard four-wire BLM fence or variation thereof.

In the few grazing allotments where there are domestic sheep, we have used barbed wire fences consisting of six strands, at six-inch intervals, from six to 36 inches above ground level. The fence is low enough to provide easy access by mule deer. We have no antelope in domestic sheep use areas on the Carson City District.

SUMMARY

When constructing fences around wildlife water developments, the species to be allowed access and those to be excluded must be considered, plus environmental and construction details, and the availability of nearby water for excluded species. Table 1 provides a matrix to guide the reader in fence selection.

The Helvie fence has been proven effective since 1972 and is used in several states where desert bighorn sheep are important. It effectively excludes cattle and burros, but a taller fence is recommended in horse areas. Rail fences of either steel or heavy wood are recommended for horse fences. The BLM standard four wire fence, as described, works well in cattle/deer/antelope areas. Securing the wire directly to collecting apron uprights has proven adequate where cattle coexist with small and nongame species. Six strand fences with a 36 inch top strand will allow deer passage but excludes domestic sheep.

Table 1. Fence types recommended around wildlife water developments, comparing animals to be excluded and animals to be allowed passage.

	Allowed Species			
Excluded	Bighorn Sheep	Mule Deer	Pronghorn Antelope	Smaller Wildlife Species
Horses	A	A, Ei G	A, E	A, E
Burros	B	B	B	B
Cattle	B	C	C	C, D
Domestic Sheep	X	F		F

Fence type:

A--Rail fence:

Steel:Posts on 8 foot centers, 3 rails 32-46-60 inches above ground, measured to bottom of rail. Wood:Posts on 7 foot centers, rails 16 feet x 3-4 inches, 28-45-72 inches along slanting pole, from bottom, pole legs 72 inches between ground ends

B--Helvie fence:

Wire: Posts on 10 foot centers; wire spacing 20, 35, and 39 inches from ground, bottom wire smooth. Can go higher but only in 4 inch increments rail Posts on 10 foot centers, rails 2 inch pipe or 4 inch wood, spaced 20-28-44 inches above ground to bottom of rail

C--BLM standard fence:

Posts on 10-16½ foot centers, wire spacing 16/18, 22, 30, 42 inches from ground, bottom wire smooth

D--Attach barbed wire to steel uprights with vertical wood poles in front of apron to protect gutter
E--Fence C with higher (46 inch) top wire
F--Posts 10-16½ feet apart, wire 6, 12, 18, 24, 30, 36 inches from ground
G--Single wood post, 2 rails: Posts 7 foot on centers, rails 30 and 60 inches above ground
X--NEVER mix domestic and bighorn sheep: 30+ documented cases throughout the Western U.S. have shown majority or all of the bighorns die, due to disease.

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A RUBBER-TIRED STOCKTANK

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Abstract

Steel tanks are normally used for water storage at spring developments. Quite often, the water is so alkaline that steel tanks will quickly rust out. The only alternative is constant replacement or use of expensive redwood tanks. A desirable alternative is the use of large junker tires off earthmoving equipment. These have several advantages; they are impervious to gunfire, will not rust out or break, absorb sunlight and melt ice in the winter, remain undamaged when frozen solid and are free for the taking.

A cement plug will easily seal the bottom. An inlet and outlet can be put in the cement plug or brought in over the top. The outer sidewall is easily cut out with a linoleum knife. The tank is then set 6 to 18 inches into the ground. This prevents movement by cattle and permits drinking by calves. To increase storage, tanks can be hooked up in tandem as needed.

The tire size can be scaled down to a size where it can be carried by a man. This permits hand development of small seeps in remote hard to get to places for big game.

Key words: tire tank, alkaline water, low maintenance, solar heating

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INTRODUCTION

Water developments all have one common component, some type of tank or storage facility, usually a galvanized steel tank. These tanks are widely used and perform very well. They do have two disadvantages. Much of the groundwater in the Western U.S. is very alkaline which causes these tanks to rapidly rust out. A second disadvantage is these tanks are easily punctured by rifle fire, resulting in increased maintenance costs. An inexpensive alternative to a steel tank is a tank made from junk tires off large earthmoving equipment. The junk tire itself is available free to anyone that will take them.

Tanks made from tires have several advantages--they are available free for the hauling, they will not rust out or break, freezing and gunfire will not damage them, and their black color absorbs heat from sunlight, providing open water during the winter.

MATERIALS

The size of tire used is generally dependent on the number of animals expected to use the tank and the source of water supply. A smaller tire can be adequate with a strong water supply and small number of animals. Conversely, a weak water source would require a large storage capacity. Depending on the size of the tire, this volume can vary from approximately 100 gallons to 1,000 gallons.

The procedure for converting a tire into a tank is the same regardless of size. To construct the tank, one sidewall must be cut out. Usually, one sidewall has a puncture in it, and that side is the one cut out. The easiest way to do this is with a linoleum knife. Numerous other ways have been tried, but nothing has been found to work better. On larger tires, spraying a lubricant into the cut greatly reduces friction between the rubber sidewall and the knife. The sidewall is cut at the apex where the edge of the tread stops on the sidewall. This is the thinnest part.

After cutting, the sidewall is lifted out and used as a mold to pour the cement plug. The sidewall is lifted out and placed outer surface up on a piece of plywood. At this point, a decision must be made on how water will be brought into the tank and whether an outflow pipe is wanted. The incoming water line can be brought over the edge of the tank or up through the plug. It is preferable to bring it up through the plug as the water in the tank helps protect the standpipe from freezing. An outflow pipe is desirable because it keeps the area around the tank dry. Without it, erosion can result in the tank being pedestalled and difficult for calves to drink out of.

If the incoming line will come through the cement plug a hole is bored in the plywood to accommodate a pipe nipple. The pipe size used must mate with the plastic line used. This hole is bored 4 to 5 inches from the edge of the cement plug. It is important this be placed near the edge rather than the middle of the plug. Otherwise, it is not possible to bend the incoming plastic pipe sufficiently to attach it to the nipple. If an outlet is desired, a second hole is bored on the opposite side of the plug (see Fig. 1).

Two handles are formed in the shape of a mill iron from rebar. Several short pieces of rebar are cut approximately three-fourths of the diameter of the plug, which are embedded in the cement. The nipple used should be long enough so that the threads just clear the top and bottom of the plug. A large washer or ring should be welded around the nipple to stabilize it in the cement and help seal it against seepage. Last, a thin covering of grease is applied to the inside of the bead. A thin covering of grease is sufficient, but it must be complete. Without the grease, it is impossible to lift the completed plug out of the mold.

The cement should not use large gravel (>1") as it is hard to eliminate air pockets. The cement should be thoroughly agitated, especially around the edges so a smooth surface results. Then the rebar is embedded in the wet cement. The pipe nipple(s) are placed in the mold before the cement is poured. After the cement plug has cured, it is lifted out of the mold and is now ready for use.

The procedure for installing the plug will vary somewhat, depending on whether water will flow through the plug. If no pipes are to be attached to the plug, the procedure is simplified. The tire must be laying flat but not necessarily level. The plug is carefully lowered through the cut out sidewall and into the intact bead. Care

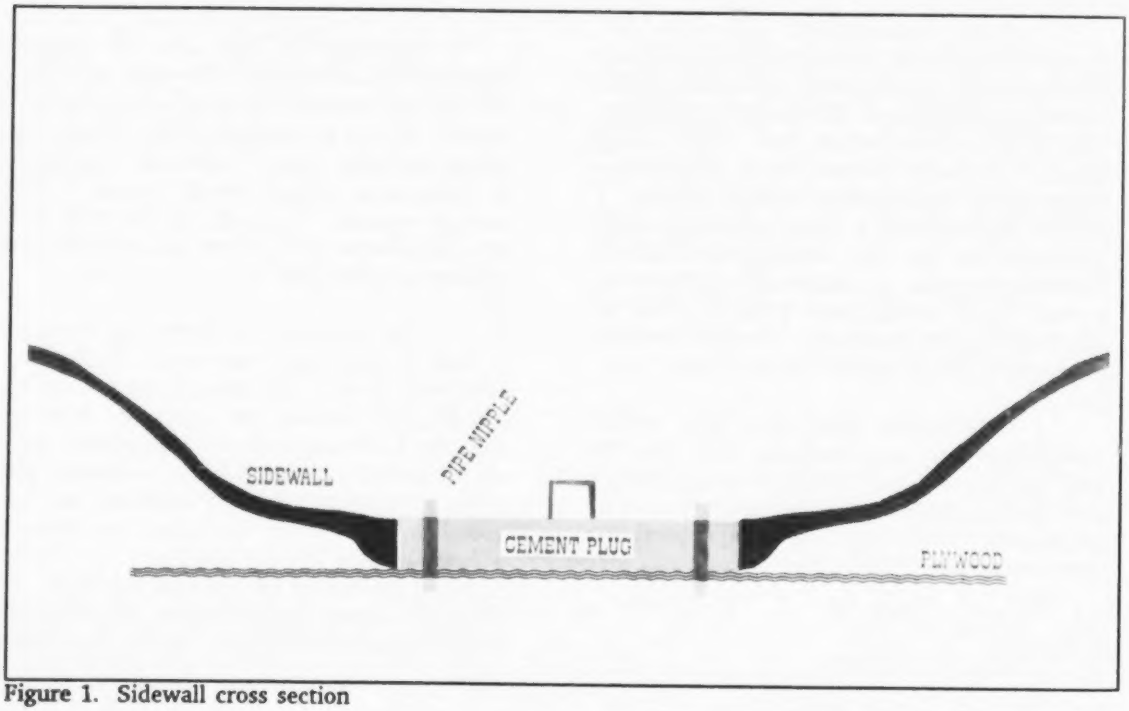

Figure 1. Sidewall cross section

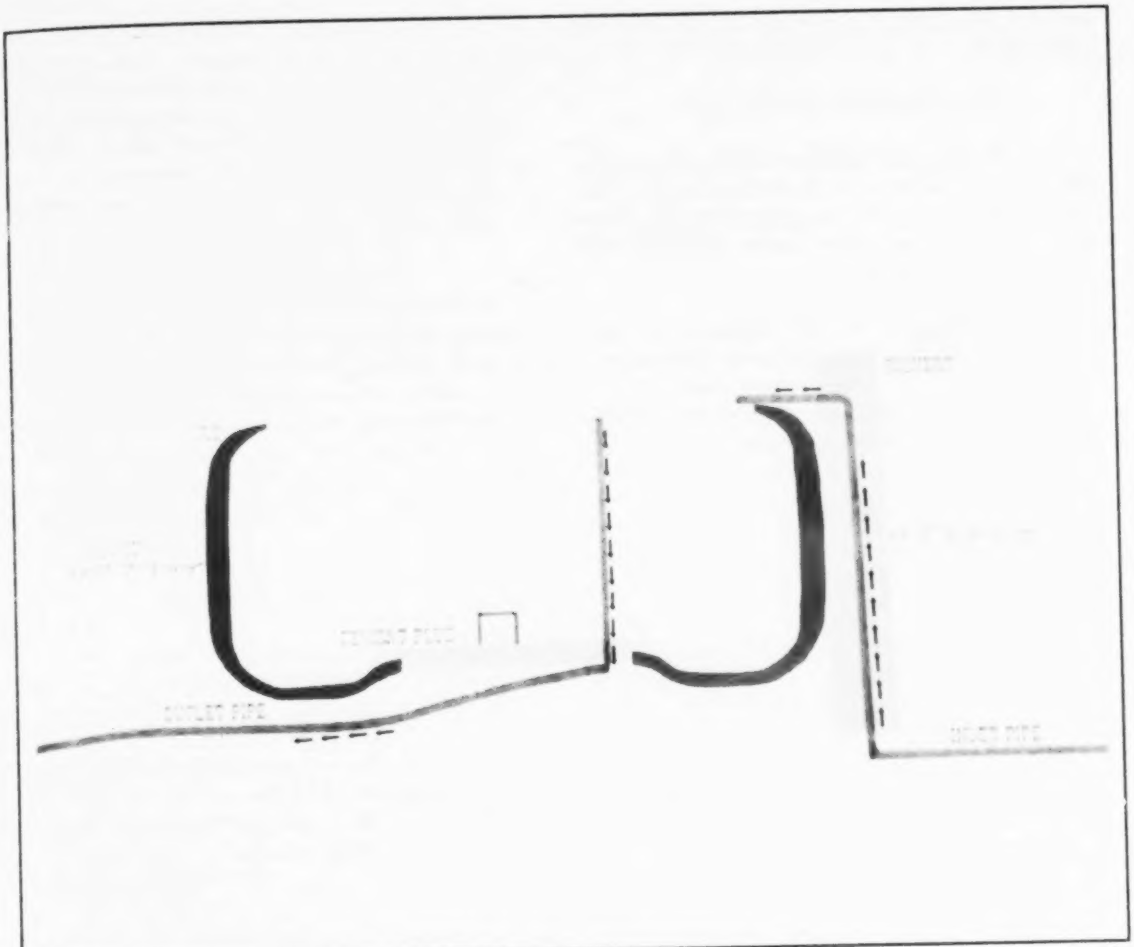

Figure 2. Cross section of completed tank

must be taken to get the plug started evenly and completely into the intact bead. Once started, light jumping on the plug will settle it in place.

If pipes are to be attached to the plug, an elbow must be screwed onto the bottom of the nipple. A pipe to slip adapter is screwed into the elbow and tightened to where it points across the plug. Next the plug is suspended 3 to 4 inches above the bead. The plastic pipe is then slipped on and a drawband tightened. Now the plug is lowered into the bead exactly as described above.

A riser pipe is attached to the top of the nipple to the desired water level. The incoming line should have an elbow and short nipple attached to the top. The nipple should point parallel to the side of the tank. This promotes the water flowing around the tank and helps retard freezing. If the inflow line comes over the side of the tank, it should be enclosed within a culvert for protection against livestock and freezing. The water inflow line should also be directed along the side of the tank (Fig. 2).

The plug will initially leak a minor amount. It will usually seal itself in a short time. A product called Flex-a-Fill (Deery Oil Co., Mack, Colo.) (reference to trade names does not imply endorsement by the U.S. Government) can be easily melted around the plug. It will seal the plug and any other holes in the line. Bentonite mixed into the water will also seal any leaks.

The tank should be dug into the ground at least half of its depth or width across the tread. This secures the tank from moving as cattle rub on it. It also makes it easier for small calves to drink. As dirt is eroded away from around the tank, it prevents the tank being pedestalled.

PERFORMANCE OF THE TANK

These tanks have been in continuous use for up to 22 years with no maintenance to the tanks themselves. The ultimate life-span of one of these tanks is unknown, but it should be well in excess of 50 years.

Where the tires are exposed to daily direct sunlight, they will not freeze other than thin surface ice that melts daily. The combination of flowing water and direct sunlight will provide open water all winter.

Should the spring cease to run after freeze up, such as happens with ephemeral springs, the tanks can freeze solid, especially if in a shaded location. When the ice melts in the spring, it will lift the plug enough to break the seal and drain the tank. To reseal it, one simply squares the plug with the bead and pushes it back down.

Small seeps inaccessible to livestock can be developed by hand using a tire tank. The tire used for this type of development would be the small balloon tires commonly used as front tires on farm tractors. Instead of a cement plug, bentonite can be used to plug the bottom.

A HEAVY EQUIPMENT TIRE GUZZLER

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Abstract

Water availability can be enhanced for many wildlife species in the desert and semidesert regions of the west by the construction of guzzlers. One of the primary concerns when building any kind of water catchment device for wildlife has to be the amount of time it will take to maintain it. Though it has not been too difficult to obtain assistance and funds to install guzzlers it is hard to obtain commitment to repair them year after year. The other concerns are ease of installation and cost. A tank built from discarded heavy equipment tires with a natural hillside for a collector is almost a maintenance free design that may fit many applications.

INTRODUCTION

A guzzler built from a large heavy equipment tire solves many of the past problems associated both with costs and ease of maintenance. Many tire companies will give old unusable tires to anyone that will take them rather than pay to discard them at a dump. In fact most companies will deliver them and this has been of great assistance since they weigh from 500 to 3000 pounds.

METHODS

The first thing that has to be done in order to convert a tire to a tank is cut out one sidewall. Though many methods have been tried the easiest found so far has been to make the cut with a linoleum knife. Anything mechanical, rapidly over heats and becomes ineffective. It is easier if some kind of lubricant like WD-40 is kept on the knife blade. The cut should be made at the thinnest part of the sidewall which is usually about where the tread stops and the sidewall starts.

Once the sidewall is removed some kind of plug must be put over the wheel hole in the other side of the tire. This has been done with 1/4" corten plate steel. Corten steel has been chosen because of some special properties that it has to form a rust coating that is airtight and prevents further rusting. The plate should be circular and approximately 2 inches larger in diameter than the hole in the tire. The next step is to drill holes in the plate every four inches around the circumference. The placement of the holes is fairly critical. They must be drilled so that the lag bolts that secure the plate to the tire just catch the edge of the tire hole. If they are too far into the tire they will hit steel cords and twist off. If they are in the right place a detectable bulge will be noted in the tire in the wheel hole. The plate is not installed in the tire until it has been placed in the final position in order to prevent pulling it loose.

The plate must be sealed to the tire with some kind of sealant and the best found to date is an oil based tar appearing product called Flex-A-Fix manufactured by Deery Oil Company of Mack, Colorado. The sealant strips are placed around the hole, ends melted together with a propane torch then each bolt is heated before it is screwed in to allow it to get through the sealant a little easier. A cover is installed on the tank for four reasons. The first is that it will keep out sunlight which will reduce algae growth. It will also slow evaporation, keep out unwanted livestock and provide an additional small watershed that will collect some water even during light showers. The cover is made of an angle iron frame covered with 1" x 4"s and sheeted with a piece of tin. It is drilled and bolted to the tire to keep people from removing it. The best way found to drill holes in the tire is with a hand operated brace and bit. All of the parts can be prepared in the shop and this saves time on installation at the site.

One of the more attractive aspects of a rubber-tired-guzzler is that it does not require an artificial watershed. After the general area has been selected several factors must be considered before final site selection. Any natural hillside will work but several criteria should be considered. The hillside should not be loose, highly erodible soil. A rocky, sparsely vegetated hill has been found to be one of the best collectors. Particle size is bigger and there has been almost no movement of material into the prototype tank. It is necessary to know approximately how much annual rainfall can be expected to calculate the amount of area that must drain into the tank to keep water in it. A suggestion is to try to capture water from an area about 6 to 8 times the size than would be needed if the watershed repelled all of the water that fell on it. This will allow for some absorption of the rain by the soil. The tank can easily be dug into a hillside in 2 hours by two people. Depending on the way in which the hill drains it may be necessary to construct two small dikes to divert runoff into the tank.

The last step is to install some kind of ramp to allow small animals to enter and leave the tank. A small expanded metal strip has worked quite well for this purpose. A short log could be used as a substitute.

CONCLUSIONS

The performance of this type of guzzler has been very satisfactory. Since the prototype tank has been installed it has never been dry and has rarely been less than half full. The water level has been monitored for the past four years. A movement activated movie camera has been mounted near the tank for several nights and small mammals and birds use it regularly. Additionally modifications can be made to this basic design to expand the uses to other wildlife such as big game.

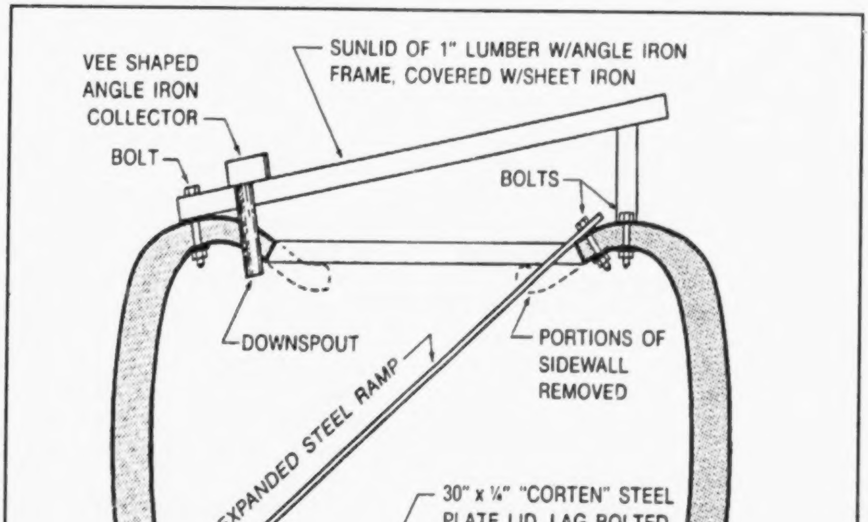
VEE SHAPED
ANGLE IRON
COLLECTOR
SUNLID OF 1" LUMBER W/ANGLE IRON
FRAME, COVERED W/SHEET IRON
BOLT
BOLTS
DOWNSPOUT
EXPANDED STEEL RAMP
PORTIONS OF
SIDEWALL
REMOVED
30" x ¼" "CORTEN" STEEL
PLATE LID, LAG BOLTED
AND SEALED

Figure 1. A cross-sectional view of the guzzler.

HORIZONTAL WELLS FOR WILDLIFE WATER DEVELOPMENT

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Abstract

The use of horizontal well technology as a wildlife habitat improvement technique is reviewed. Information related to site selection, methodologies, effectiveness, and costs is provided. Application of this technique is encouraged, particularly at sites that historically produced water but no longer generate surface flows.

Keywords: Horizontal wells, habitat improvement, water development, drilling, mountain sheep *Ovis canadensis*.

INTRODUCTION

Information included in this paper has been taken directly from two previously published papers (Bleich 1982, Bleich et al. 1982) which detailed the application of horizontal well technology to wildlife water development programs. As a review paper, it brings together in one location information detailing site selection, methodology, costs, effectiveness, and advantages of this technique. Where appropriate, information has been updated to reflect current cost estimates as well as recent taxonomic changes. A cautionary note regarding the use of helicopters also has been included.

The evolution of the horizontal well, first as a drain for the construction industry, and later as a method of obtaining water for domestic use or livestock, has been detailed by Tripp (1963), Welchert and Freeman (1969, 1973, 1976), and Summers (1973). This technique is not well documented in wildlife science literature nor do recent reviews of drilling technology (Lehr and Campbell 1973, Paone et al. 1968, Scott and Scalmanini 1978) or habitat improvement techniques (Graf 1980, Yoakum et al. 1980) make mention of horizontal wells.

Wildlife species have benefitted from horizontal wells developed for domestic livestock. However, horizontal well methodology only recently has been applied specifically to the management of wildlife habitat, and its future appears promising (Coombes and Bleich 1979). Unfortunately, this technique is not well known, and only rarely has it been applied specifically to improving wildlife habitat.

Most wildlife biologists are not familiar with literature on horizontal well technology, except possibly the work of Welchert and Freeman (1973). The objectives of this review are to make readily available some basic information on the horizontal well as a wildlife habitat improvement technique to wildlife professionals in order to provide insight into the actual development process and to detail some of the benefits that may be associated with horizontal well technology. Additionally, the pertinent literature on the subject has been summarized.

It is axiomatic that food, cover, and water (Leopold 1933) are necessary to support wildlife populations. Weaver et al. (1958, 1959) noted that "water, or the lack of it, is a major controlling factor on game populations in arid areas." Even relatively well-watered areas often have dry localities where water development may increase the carrying capacity of the range by allowing populations to use habitat normally unavailable because of the absence of water (Call and Mahon 1979; Weaver et al. 1958, 1959).

Until recently, subsurface water was made available for wildlife by using hand tools and occasionally explosives or by the removal of phreatophytes (Biswell and Schultz 1958; Halloran and Deming 1956, 1958; Mahon 1971; Weaver et al. 1958, 1959; and others). Indeed, Weaver et al. (1958, 1959) concluded that hand tools were the most important items used in developing springs for wildlife use. Although traditional development techniques remain important, the application of horizontal well technology to a vigorous water development program offers many opportunities to increase water flows in areas previously dismissed as impractical or impossible to improve.

Development with hand tools has several basic flaws: (1) it is not possible to control the flow of water from the spring; (2) a variable flow may be inadequate to generate enough water to create a surface source; and (3) the exposed spring water and the spring area are readily susceptible to contamination. The horizontal well eliminates these disadvantages. The flow can be controlled by a float or a gate valve. These options decrease the likelihood of unnecessary water draining from underground aquifers. Additionally, the cased well decreases the possibility of contamination, providing a source for potential users that may help to discourage vandalism (Welchert and Freeman 1973).

Maintenance requirements of horizontal wells are minimal. Water is brought to the surface by gravity flow, so no pumps are necessary. The only moving parts are a float valve, a vacuum relief valve, and a shut-off valve. The greatest advantage of the horizontal well, however, is that substantial water yields can be developed where little or no surface water previously was available. Much of what follows relates to the potential application of horizontal well technology in the arid Southwest.

The Southern California Safari Club donated a horizontal well drilling machine to the California Department of Fish and Game. W.T. Welchert and W.C. Fairbanks gave freely of their time and provided several obscure references. The helpful comments of C.S. Edon, P.W. Gelfand, S.A. Holl, R.A. Weaver, and R.T. Bowyer are appreciated. The majority of this paper was reprinted from two previously published papers, with permission from the Wildlife Society and the Desert Bighorn Council. Preparation of this review was supported by grants from the Society for the Conservation of Bighorn Sheep, Sacramento Safari Club, and California Association of Professional Scientists, while the author was on leave from the California Department of Fish and Game at the Institute of Arctic Biology, University of Alaska, Fairbanks. Special thanks to Tina Freer for her help with the preparation of this review.

METHODS

Site Selection

This is one of the most difficult and important steps in the development of a successful horizontal well. The driller must evaluate a number of parameters including: (1) the presence of historical springs and seeps, (2) the distribution of phreatophytes, and (3) the presence of an appropriate geological formation (Welchert and Freeman 1973). However, the presence of these factors does not necessarily guarantee a successful well.

Many sites in the deserts of southern California that historically produced water are now dry (Weaver 1973; Weaver and Mensch 1970). These sites are well documented and provide a logical place for consideration of development.

The presence of phreatophytes is an important indicator of subterranean water, and it may be useful in selecting a site for horizontal well development. Mesquite (Prosopis spp.) generally is considered to be indicative of a shallow water table. However, Phillips (1963) presented convincing evidence that although mesquite is present, water may be too deep for practical development. Moreover, Weaver et al. (1958, 1959) concluded that mesquite, by itself, "... is not a positive indicator of water at any depth."

Other species of phreatophytes that are good indicators of water near the surface include arrowweed (Pluchea sericea), rose (Rosa spp.), palms (Washingtonia filifera), willow (Salix spp.), and reed (Phragmites communis). The presence of salt grass (Distichlis spicata) or other grasses generally suggests favorable moisture conditions (Weaver et al. 1958, 1959). The condition of the plants at a proposed development site is an important consideration. For example, water-stressed vegetation is likely to indicate less than ideal conditions. For a more detailed treatment of vegetation as an indicator of ground water, see Meinzer (1927).

Suitable geologic formations also are necessary for successful horizontal well development. Welchert and Freeman (1973) described two formations that generally are suitable for such development. The dike formation is a tilted, impervious formation, such as clay or rock, that forms a natural barrier to an aquifer. Water at such sites is always not visible, or it may seep over the top of the barrier or through cracks in the dike. The contact formation consists of a perched water table over an impervious material and is more difficult to recognize than is the dike formation. Water usually seeps out near the outcropped impervious layer. The line of seepage often may be located by the presence of phreatophytes.

To develop a dike formation spring, the impervious barrier must be penetrated below the seep to tap the stored water. A contact formation spring is developed by penetrating at or above the seep; drilling often will fail to increase the yield. The equipment must be placed effectively in a location where the angle of drilling will reach the water supply.

At times almost any spring is capable of generating enough water to flow a considerable distance. Often, the initial flow is above ground, then it submerges after a distance, only to resurface farther down a wash. If the driller is not mindful of this possibility, he could find himself drilling for nonexistent "stored" water (Coombes and Bleich 1979).

Equipment and Operation

Most sites are in remote areas with rugged terrain. Therefore, the drilling equipment must be light and portable. Our machine weighs 770 kg and can be towed to sites that are accessible by land vehicles. Unfortunately, many sites where horizontal well methodology is applicable are accessible only by helicopter.

Because of the weight of the machine and the often unpredictable flying conditions encountered in desert regions, a helicopter with a lift capacity of at least 900 kg is necessary to move the machine into remote sites safely. Our equipment can be separated into two parts for transport by light aircraft, but reassembly problems may arise while one part of the machinery is suspended below a hovering helicopter. The relative instability of many lighter ships makes it both difficult and dangerous to carry out the above procedure. it also is necessary to transport >1000 liters of water, pipe and fittings, a pressure tank, portable pump, hoses, hand tools, other miscellaneous equipment, and two personnel, either by land vehicle or helicopter.

Development begins with drilling, using a rotary drill and recirculating water to remove drill cuttings. The drill stock is an extra strong length of 6.5-m x 32-mm (21-ft x 1 1/4-in) steel pipe and is rotated in a chuck at approximately 100 rpm. The chuck and drill stock are moved forward by a hydraulic system along a steel carriage. The hydraulic system is powered by a 16 hp gasoline engine mounted on the well machine.

In normal drilling the drill stock is fitted with a bit made from a standard pipe coupling to which a pair of tungsten-carbide tips have been welded. For drilling in extremely hard rock, the drill stock may be fitted with a diamond bit or special rock bits, similar to those used in the petroleum industry.

The bit cuts a hole about 7 mm (1/4 in) larger than the coupling. Water is pumped from a 200-liter (55-gal) drum through the drill stock. The water cools the bit and removes the cuttings by flushing them through the annular clearing between the hole and the drill stock. To conserve water the returning flow is diverted into a 200-liter drum where the cuttings settle and the overflow is directed back to another 200-liter drum by a 50-mm (2-in) pipe. The pump then picks up and recirculates this water.

The drilling machine is operated by two hydraulic systems. One system provides power for the drill chuck rotation. The second hydraulic system operates the movement of the chuck assembly along the carriage and is used to move the rotating drill stock into or out of the hole being drilled. By using a series of simple controls, the operator can vary the rotational direction and the amount of forward thrust placed on the drill stock. Drilling speed is a function of the type of bit used, the rotational speed of the drill stock, the type of material being drilled, and the thrust applied to the drill stock by the operator.

Drilling continues until production of water is evident or until the operator decides that the well will be dry. If water is reached, a standard 50-mm pipe equipped with a carbide bit is used to ream out the bore hole using the drill stock as a guide. Drilling ceases when the impervious layer is reached. The 50-mm pipe serves as the casing for the well, and enough is left exposed for attachment of proper plumbing.

The drill stock is removed, and a second hole adjacent and parallel to the casing is drilled for 3 m to serve as a guide for the return flow of cement slurry that, when set, keeps the casing in place and allows water tapped to flow through the casing only.

The cement slurry is mixed and placed in a pressure tank. Water pressure from the pump forces the mix through the drill stock and into the annular space surrounding the casing. Once evidence of cement appears in the casing return flow, the drill stock is then removed and the cement is left overnight. Drilling then continues through the casing until the desired flow of water is attained or until a practical drilling limit is reached. The drill stock is them removed, and a perforated 32-mm (1 1/4-in) pipe is inserted as a "pickup" line to keep the well open. This pipe extends from 100 cm inside the casing on into the aquifer.

Plumbing Connections

Simple plumbing connections can be designed to suit the intended application of each horizontal well. Generally, a bell reducer is connected to the casing, and a "T" is attached, via a nipple, to the reducer. A vacuum relief valve that prevents a build-up of negative pressure in the casing is attached to one end of the "T", and a gate valve is attached to the other.

From the gate valve a pipeline can be run to a concrete drinking basin that may be fitted with a float valve to conserve water. We have, however, found that commercial steel cattle troughs fitted with float valves are superior to masonry basins.

If the well is located in an unstable location such as the middle of a wash, a box can be built around the well head to protect it from damage by heavy storm runoff. A pipeline attached to the well head can transport the water to a more suitable location. Ranchers in Arizona have run pipelines to drinkers located as far as 16 km from a horizontal well (Welchert and Freeman 1976).

COSTS

Development costs of horizontal wells do not differ greatly from costs associated with more traditional spring development techniques. The initial cost of the machine, however, is high. At present, the cost of a good, dependable horizontal well drilling machine and associated equipment is approximately $15,000. While fiscal constraints may preclude purchase of this type of equipment by agencies not fortunate enough to already own one, drilling contractors are available to develop horizontal wells for wildlife purposes.

The Department of Fish and Game has maintained records on the cost of materials for only six wells which have been attempted (Table 1). The average cost of materials per well, including materials irretrievably committed during the development process, and estimated costs for maintenance and expendable materials, was $350.00 (1988 dollars; Table 1).

Manpower requirements during operation of the horizontal well machine are no more than would be expected with more traditional development efforts. Although one man can operate the machinery and complete a horizontal well, it is not recommended. Because of the safety hazard involved in operating sophisticated machinery of this type, two persons should be present at all times, particularly in remote areas.

Development costs and manpower requirements escalate rapidly if helicopter transport of the machinery is necessary. At current rates, helicopters with an external lift capacity adequate to safely transport each 390 kg half of our drilling machine cost approximately $425 per rotor-hour. Helicopters capable of moving the machine in one piece are extremely expensive, ranging from $700 to over $1,200 per rotor-hour. It should be remembered that helicopter ferry costs must be included when calculating the cost of helicopter transport. Sites in remote locations may not be practicably developed using horizonal well technology because of the extreme costs involved in just getting the equipment into and out of the site.

Although Thompson and Baker (1981) have recommended that wildlife agencies take

Table 1. Cost of materials for six horizontal wells developed by the California Department of Fish and Game.

Item	Average Amount	Average Cost
2 inch casing	62 feet	$163.00
1.25 inch pickup pipe	20 feet	$ 36.00
plumbing parts	1 reducer, 1 valve	$ 22.00
cement	4 sacks	$ 41.00
other*		$ 88.00
Total Cost Per Well		**$350.00**
Cost of plumbing materials per well		$221.00

*expendable materials, equipment maintenance, etc.

advantage of offers of "free" helicopter time, Bleich (1983) has presented convincing arguments against that strategy. In fact, one operator, working for "free", dropped our horizontal well machine from a height of 300 m, causing extensive damage.

Manpower costs are increased when transporting equipment by helicopter, because it is necessary to have at least six people present to assist with the disassembly and reassembly of our equipment before and after helicopter transport, if the machine must be moved in two pieces. Of course, only two persons need remain on site during the development process; however, additional personnel are required when removing the machine from the site, for reasons pointed out above. The dangers inherent in assembling and disassembling this equipment while it is suspended below a hovering helicopter were discussed earlier. Again, if the site is remote, commitments in manpower and time can become substantial.

Welchert and Freeman (1969) reported an average development time of 32.3 hours per producing well, of the 45 wells on which they maintained records. It is estimated that each of the wells the Department has developed to date has averaged approximately 40 hours of drilling, a figure not greatly different than that reported by Welchert and Freeman (1969).

DISCUSSION

Several advantages make horizontal well technology a desirable water development alternative. First, horizontal wells greatly increase the success rate in spring development, particularly in arid regions where historical water sources may have dried up. Second, the horizontal well provides a method of controlling the amount of water flowing from a spring, reducing water waste which is advantageous, especially in extremely arid regions. Third, the spring is not readily subject to contamination, thus providing a sanitary water supply. Fourth, horizontal wells are relatively inexpensive to develop, except[1] when equipment must be transported by helicopter. Maintenance costs are low, and there are no operational costs. Finally, there are no moving parts (aside from a float valve and vacuum relief valve) in a horizontal well system. The chances of mechanical failure are extremely low, an important consideration in remote regions.

In California the Department of Fish and Game has used this technique successfully to improve water supplies for many native wildlife species. One species that has benefitted particularly is the mountain sheep (Ovis canadensis). Although ecotypes of mountain sheep inhabiting desert regions have evolved physiologically efficient methods of maintaining water balance (Turner 1973), they require free water (Blong and Pollard 1968). Weaver (1973) documented the disappearance of mountain sheep from several areas in California now deficient in water, but which historically had adequate water supplies. Indeed, the disappearance of surface water at historical springs may have contributed to the extirpation of mountain sheep in several California desert mountain ranges. However, even with horizontal well technology, it may not be possible to restore adequate surface water at every historical spring.

In addition to mountain sheep, this technique has been used successfully to make water available for such big game animals as wapiti (Cervus elaphus), mule deer (Odocoileus hemionus), and pronghorn (Antilocapra americana). Other game species that have benefitted include sage grouse (Centrocercus urophasianus), chukar (Alectoris chukar), California quail (Callipepla californicus), Gambel's quail (Callipepla gambellii), mountain quail (Oreortyx pictus), and mourning dove (Zenaida macroura). Additionally, numerous species of nongame birds and mammals may benefit from the production of water at sites which historically had not even produced a surface flow.

Clearly, populations of both game and nongame species will benefit from the wider application of horizontal well technology which is a valuable, cost effective technique, readily applicable to wildlife habitat management programs.

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STRATEGIC PLACEMENT OF ARTIFICIAL WATERING DEVICES FOR USE BY CHUKAR PARTRIDGE

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Abstract

Since the establishment of chukar partridge (Alectoris graeca) in Nevada, wildlife biologists have observed voids in their population occurrence on many mountain ranges and in their failure to establish on others. They further observed that many of these areas had the habitat components of food, escape and roosting cover, but lacked water. Guzzlers were installed to meet this need but bird establishment on the units was usually low if at all. A decade of evaluation of units identified three major concerns which eventually proved helpful in creating good chukar populations using artificial watering devices.

1. Units must be placed where water is the only component missing in the chukar's habitat requirements.
2. Units must be placed in locations where a natural spring would most likely occur.
3. Units should be spaced at up to one mile intervals in a mosaic with natural springs.

Guzzler placement using these criteria has improved chukar brooding success. Populations vary from 50 to 300 birds per unit on peak production years. Many mountain ranges previously unhunted or hunted intermittently are experiencing increased hunter use, success and improved hunter distribution.

INTRODUCTION

The Nevada Department of Wildlife has long recognized the shortage of upland game species and the need to increase upland game hunter recreation in Nevada. Chukar have filled that need more than any other species.

In northern Nevada, chukar population occur primarily in the 5,000 to 7,000 foot elevation zone where annual moisture averages eight to ten inches. Adequate free water is not always present or evenly distributed throughout this zone for maximum utilization of the available habitat by adult chukar during the critical brood rearing season. Proper placement of guzzlers can increase chukar numbers by increasing brood production where water is scarce or unevenly distributed. New populations can be created where water is nonexistent if other habitat components are present.

A basic understanding of guzzler placement techniques, however, is crucial to the successful use of the unit by chukar partridge.

BACKGROUND

Guzzlers have been installed to improve or expand chukar populations since the mid-1950's. For much of the period that followed, chukar populations were at high levels statewide with relatively light hunting pressure. This resulted in the Department of Wildlife feeling little need to research the potential for expanding chukar range using guzzlers. Initially, there was only limited success with the guzzlers installed which further decreased interest in water development. Units were placed in all types of locations: on hill tops or partially down the slopes; in wide canyons 300 or more feet from steep escape cover; near other undiscovered seeps; on open flats, etc. Most did not receive even minor use. It was felt at the time that the birds would search out water wherever it was and adapt to using it in that location. This proved not to be the case. Even with natural springs, many are not used because they do not meet all of the chukar's requirements. Chukar are rigid in their selection of a summer water site, because they are raising weak flying young at the time that they are dependant upon free water.

METHODS

When evaluating a mountain range for possible guzzler development, a complete mapped inventory of all creeks, spring and seeps must be made. It has been my experience that many more springs and seeps exist in an area than are located on U.S. Geological Survey 7.5 minute and 15 minute maps. A thorough search of the area along with interviewing people familiar with the area must be made. Long narrow canyons, one to five miles in length, are preferred by Chukar (see Figure 1). Ranges with long rolling hills with little definition and few or no rock piles do not qualify. If possible, initial attempts at guzzler placement should be made on ranges with established chukar populations. If you are able to establish chukar broods on the new unit, you will have the knowledge and experience needed to pursue development on a larger scale. Chukars need free water from mid-June through October, or about four to five months, depending on the weather. This time frame coincides with the brooding period; therefore the units need to be placed where chukar broods preferred habitats are found along the canyon bottoms where the best soils, vegetation and insect life are available adjacent to water and escape cover.

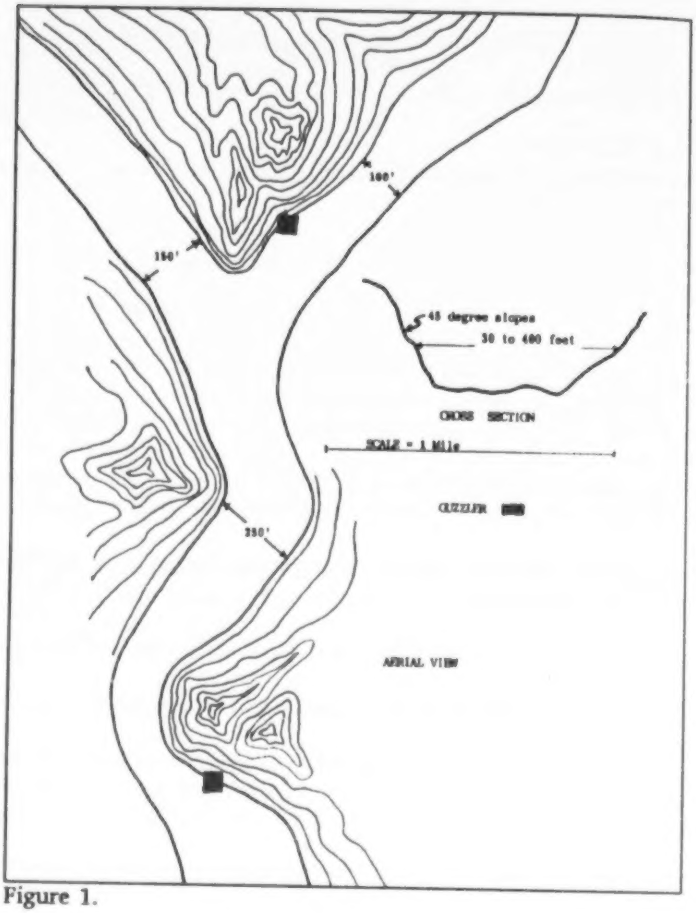

Figure 1.

Three major hypotheses were concluded which proved successful in placement of guzzlers:

1. Units must be placed where water is the only component missing in the chukar's habitat needs. Units should be installed in the big sage (Artemisia tridentatia) zone where adequate moisture assures annual grasses, especially cheatgrass (Bromus tectorum), and forb crops except on severe drought years. Units place on drier sites, such as in the shadscale (Atriplex canescens) bud sage (Artemisia spinescens) zone, will not build a significant bird population because of food limitations. Severe wildfire where sagebrush has been eliminated will preclude chukar establishment on a unit until this overstory is restored.

2. Units must be placed in locations where a natural spring might occur. Chukar, like humans seek water in certain natural settings. These sites are in narrow canyons (usually 30 feet to 400 feet wide between 45° slopes) where a natural constriction would bring underground water to the surface. Several natural sites occur in any long canyon. This site usually possesses escape cover such as a steep hill or cliffs within 10 to 30 feet of the site. This also meets the needs of the young birds by putting them on the

best soils and vegetation in the area during the summer brooding period.

3. The Guzzler Complex: Units should be spaced approximately one mile apart in a mosaic with natural springs. Although production can vary considerably from year to year at each water site, in most years production outstrips the carrying capacity of the immediate habitat; thus brood stock is readily available to occupy or reoccupy adjacent vacant brooding areas. More complete use can be made of the prime brooding areas in canyon bottoms with proper water distribution when it is realized how closely the young birds are tied to water. Helicopter surveys conducted during the Trinity chukar study (Stiver, 1988) reveal that 85 percent of the birds surveyed were within a one quarter mile radius of water; that means that 85 percent of the chukars were utilizing only 10 percent of the available habitat during the summer brooding period.

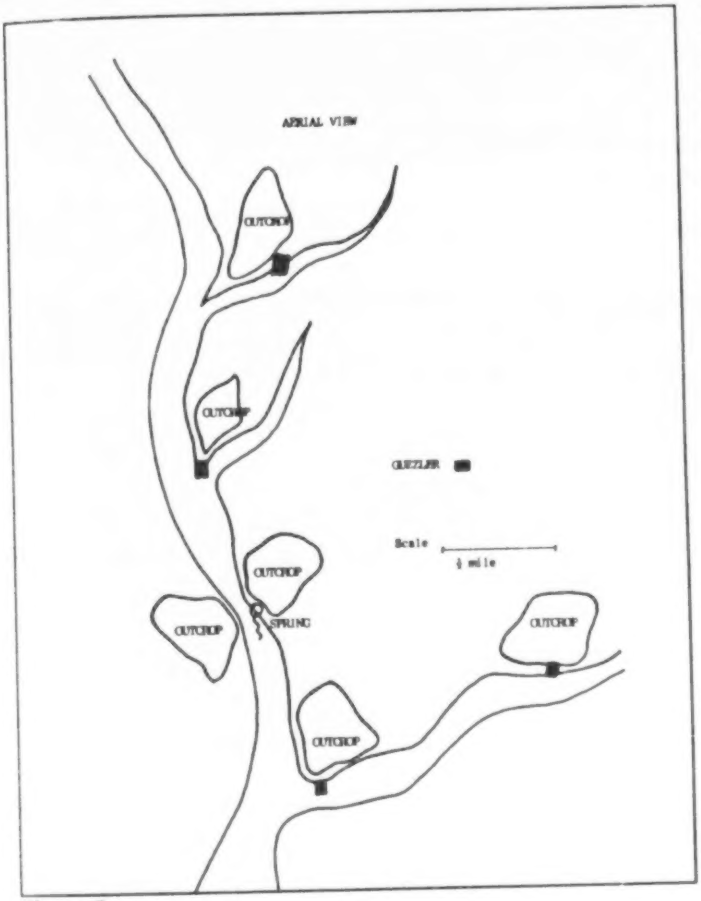

Figure 2.

RESULTS

Population establishment can be rapid; occurring in most cases the first year of water development if brood stock is available and the other habitat components are present. If all of the criteria have been followed and birds do not establish or are slow in establishing, we have found that it is usually caused by drought or some fluctuation in food supply. Other less understood causes may apply such as an area prone to winter kill.

Young chukar water daily when temperatures exceed 100° F although adults may still not water for a week or more. On a good production year, up to 70 percent of the chukar present at a unit will be birds of the year, emphasizing the value of water on brooding areas.

DISCUSSION

In Nevada, much more can be done to improve chukar distribution with guzzlers. At present we have increased the population of birds on many mountain ranges by improving water distribution. This includes the Trinities, West Humboldts, Seven Troughs, and Selenite ranges among others. Essentially complete new populations have been established on the Sand Springs Range, Dry Mountain and Buffalo Mountain. Other ranges such as the Nightingales and the Truckee Range have not yet established suitable populations due to drought on the former and drought and marginal habitat components on the latter.

The extent of use by nongame wildlife and furbearers has not been documented but everything from coyotes, bobcats, and kit foxes to passerine birds and reptiles have been observed commonly using the units. Mourning doves and cottontail rabbits adapt quickly to new guzzler placements.

Experimentation with guzzler design for our northern Nevada rainfall zone (8 to 10 inch average) has enabled us to design a unit more suitable to this area, cutting costs by 50 percent and eliminating our need for heavy equipment for installation. An entire unit can be carried in one load in the back of a pickup and installed with hand tools in two to five hours by two men. Material costs are $ 750.00.

CONCLUSION

For a guzzler development to be successful, the three basic guidelines must be followed. It is particularly important to place the unit within 100 feet (preferably 10 to 30 feet) of a cliff or 45° slope. Because of the difficult terrain, units are often placed too far from necessary escape cover, which is the single most frequent failing in artificial water development for chukar partridge.

Nevada's guzzler development program has had a high degree of success. In some instances a population of 250 to 300 birds has been established per unit. When the three basic guidelines are followed, success is expected and the number of birds on a particular unit is fairly predictable.

Nevada's guzzler program is still in its early stages with many other mountain ranges available for development. Guzzler spacing within different habitats and geographical sites needs more research. Preliminary observations are suggesting that units may continue to receive significant bird use when spaced as little as one-third mile apart.

Private funding from groups interested in upland game hunting is now becoming available along with public funds to accelerate guzzler installations. Volunteer labor is also available and very helpful. The future looks bright for expanding chukar range proper installation of guzzlers.

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Evaluation

MECHANICAL EVALUATION OF ARTIFICIAL WATERING DEVICES BUILT FOR MOUNTAIN SHEEP IN CALIFORNIA

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Abstract

Twenty-two artificial watering devices for mountain sheep were evaluated from 1978-1988. Ninety-eight mechanical failures were recorded over 2,904 guzzler-months. Each guzzler was functional an average of 87% of the eleven year period. Freezing, float valve malfunctions, and rusting covered the majority of the reported problems. Recommendations to reduce potential problems are included. Manpower sources for the reported inspections are identified and analyzed.

Keywords: Catchment, evaluation, guzzler, maintenance, mountain sheep, Ovis canadensis, volunteer, water.

INTRODUCTION

The California Department of Fish and Game (CDFG) has had an active, productive, and effective wildlife water development program for many years. A diversity of techniques, including the use of hand tools, explosives, herbicides, and horizontal well technology (Biswell and Schultz 1958; Halloran and Deming 1956, 1958; Mahon 1971; Weaver et al. 1958, 1959; Bleich 1982; Bleich et al. 1982a; Coombes and Bleich 1979) have been used to enhance the flow of water from desert springs, in efforts to increase its availability to wildlife. Additionally, where it was not possible to make water available at natural sources, the use of artificial catchments (guzzlers) has been employed (Glading 1947, Bleich 1983, Bleich et al. 1982b).

The first upland game guzzlers were installed in California in 1942 (MacGregor 1953). The first six big game guzzlers were constructed in the early 1950's to benefit mule deer (Odocoileus hemionus) in arid southern California and, in 1965, a seventh big game guzzler was constructed in the Santa Rosa Mountains in an effort to provide permanent water in a part of that range used only seasonally by mountain sheep (Ovis canadensis).

As a result of recommendations put forth by Weaver (1973), a program was developed to construct a series of guzzlers, in water-deficient areas, to enhance habitat for mountain sheep; a total of 22 big game guzzlers were built between 1971 and December, 1977. Big game guzzlers constructed since 1971 have been designed primarily to catch storm water from slick-rock "aprons." The guzzlers, and their construction, have been described by Massie (1975), Carpenter (1976) and Bleich et al. (1982b). "California" style big game guzzlers recently have been installed in Arizona (Werner 1984).

Of the total of 29 big game guzzlers in southeastern California at the end of 1977, six were designed to capture runoff from artificial aprons, and stored it in underground storage tanks constructed of fiberglass or of concrete, and one was a commercial style catchment utilizing an inverted sheet-metal "umbrella" above the storage tank to collect rainfall (manufactured by the New Mexico Tank and Culvert Company, Albuquerque, New Mexico). Two of the units used cast fiberglass swimming pools as storage tanks (Garton 1956a, 1956b).

Guzzlers constructed between 1971 and 1977 utilized a series of 3, above-ground metal (or plastic) tanks, which stored approximately 20,000 liters of water. With three exceptions, water collected on natural rock aprons was channeled to the tanks by way of a gully plug, equipped with a 50 mm pickup pipe and filter to keep sand from entering the tanks. Water was available for wildlife at a float-valve controlled drinker, plumbed to the tanks (Bleich et al. 1982b).

To date, only one formal evaluation of small game guzzlers in California has been conducted (Lewis 1973). As of 1978, no formal evaluations of big game guzzlers had been conducted. That year we began an intensive, long-term evaluation of the big game guzzlers which had been installed in the arid regions of southern California. The evaluation considered: (1) use and effectiveness of big game guzzlers, and (2) aspects of design, construction and mechanics (Bleich et al. 1979). Results of the mechanical evaluation of 22 big game guzzlers constructed from 1971-1977 are presented in this report.

The effectiveness of the Volunteer Desert Water and Wildlife Survey (VDWWS) (Bleich et al. 1982b) as a means to assist with the inspections of big game guzzlers also is assessed. In 1985, the bulk of the inspection responsibilities were turned over to VDWWS, because of cutbacks in CDFG funding. Since that time, volunteers have accepted much of the responsibility for routine inspections, while CDFG personnel have accepted responsibility for needed maintenance. In 1985, the Bureau of Land Management assumed both inspection and maintenance responsibilities for one catchment under evaluation.

We thank the many participants in the Volunteer Desert Water and Wildlife Survey who, over the years, have contributed so much to CDFG's desert water development program. The Society for the Conservation of Bighorn Sheep (SCBS) played a major role in founding VDWWS, and continues to support it strongly. We thank Glenn Sudmeier and Don Jones for their roles, for revitalizing the Area Captain Program. The majority of these catchments evaluated herein are on public lands administered by the Bureau of Land Management. Preparation of this paper was supported by SCBS, the Sacramento Safari Club, and the California Association of Professional Scientists while the senior author, on leave of absence from CDFG, was at the Institute of Arctic Biology, University of Alaska, Fairbanks. This is a contribution from California Federal Aid in Wildlife Restoration Project W-26-D. We extend a special thanks to Tina Freer for typing the manuscript.

METHODS

All big game guzzlers constructed from 1971-1977 were mechanically evaluated from 1978-1988. Evaluations of those big game guzzlers constructed prior to 1971 are not included here because of their inherently different design features. Twenty of the 22 units discussed herein store water in above-ground storage tanks; two store water in 40,000 L underground concrete tanks. Nineteen of the guzzlers capture storm runoff with concrete gully plugs; two capture water off of the asphalt surface of Interstate Highway 40, and one captures water from a weakly flowing natural spring. All use a float-valve operated system to make water available to wildlife at a drinking trough.

An effort was made to inspect all big game guzzlers at least twice a year; in some cases, many more inspections were recorded. Personnel from the California Department of Fish and Game and members of the Volunteer Desert Water and Wildlife Survey performed regular inspections and maintenance. Limited assistance was received from other agency personnel.

During inspection trips, each guzzler was thoroughly inspected for mechanical problems, and minor maintenance occasionally was performed. Minor maintenance consisted primarily of cleaning the drinking basin of algal growth, adjusting float rods, or opening or closing water control valves to decrease mechanical failures due to freezing (Bleich et al. 1979). During each visit, personnel completed a one-page inspection sheet, noting on it their activities, condition of the catchment, work done or needed, amount of wildlife use, and recommendations for additional maintenance. Inspection forms were submitted to CDFG, and logged into a permanent file. Necessary major maintenance was scheduled for completion at a future time. Occasionally, catchments were not functional for extended periods of time.

Permanent inspection and maintenance records for the 22 catchments were evaluated for the 11-year period, 1978-1988. Although some records existed for the period 1971-1977, these were omitted from this analysis because record-keeping was incomplete, and no permanent file of inspection results was maintained. Hence, the possibility exists that not all problems which were encountered were properly recorded.

Problems encountered during the inspections were categorized as one of five types: (1) problems related to freezing; (2) float-valve failures; (3) "natural disasters" other than freezing; (4) construction-related problems; and (5) others. Construction-related problems were those which resulted from incomplete or improper assembly during the initial construction of the catchment. "Natural disasters" included damage from wind, rain, landslides, or falling rocks. Problems categorized as "others" included rust, and repairs necessitated by human modification of the guzzler.

Careful tallies of those persons performing inspections were maintained, and they are evaluated in an effort to assess the effectiveness of the Area Captain Program of VDWSS. That program emphasizes an organized approach to catchment inspections and is designed to minimize inspections by CDFG personnel. Budgetary constraints implemented in 1985 resulted in a 29% decrease in manpower available to the CDFG habitat management project in southern California, necessitating a greater dependency on volunteer participation.

RESULTS

From 1978-1988, 22 big game guzzlers were inspected and/or maintained a total of 698 times ($\underline{\bar{X}}$ = 31.7, SD = 9.4). During the same time period, a total of 98 mechanical problems were recorded, resulting in a total down-time of 381 guzzler-months, or 13.3% of the total 2,904 guzzler months included in this study. Down-time ranged from 0% to 86% of the total time each guzzler potentially was in service (Table 1).

Frozen pipes and/or valves accounted for 35 of 98 (35.7%) mechanical problems encountered, followed by float-valve failures 31/98; 31.6%), construction flaws (9/98; 9.2%), and natural disasters (6/98; 6.1%). "Other" failures, including rusted tanks, rusted drinkers, and man-caused damage accounted for 17 of the 98 failures (17.4%). Each guzzler under evaluation suffered an average of 4.4(± 2.6) mechanical failures over the eleven-year evaluation.

A total of 698 inspections were conducted by agency personnel or volunteers during the 11-year evaluation (Table 2). Prior to the onset of the Area Captain Program in 1985, CDFG personnel had performed the vast majority (436; 88.1%) of the 495 inspections recorded. Volunteers performed 48 (9.7%) inspections, and other agency personnel performed 11 (2.2%) inspections. During the 4-year period that the Area Captain Program has been in effect, 203 inspections have been recorded. Volunteers performed 102 (50.2%) of them, CDFG performed 97 (47.8%), and 4 (0.2%) were performed by other agency personnel.

DISCUSSION

Five major causes of big game guzzler failures were identified: freezing, design problems, float valve failures, natural disasters (other than freezing), and "other" mechanical failures (consisting primarily of oxidation of metal tanks or other rust-related problems).

Freezing. Thirty-five (35.7%) of the 98 recorded malfunctions were caused by cold weather resulting in broken pipes, fittings, or valves. Although all plumbing was either insulated or buried, cold weather remained the primary cause of guzzler malfunctions. Initially, we used fiberglass batting for insulation but rodents removed it from pipes, and the material itself accumulated moisture from rain or snowmelt, decreasing its insulative properties. Self-adhesive aluminized foam pipe-wrap was used successfully but, even when it was painted flat black, it remained attractive to rodents. Closed-cell foam pipe "jackets" have been used in the recent past, but this material has not yet been fully evaluated. Burying the plumbing appears to be an effective means of preventing freeze breaks; however, thundershowers necessitate a constant program to keep the pipes buried.

Table 1. Types of problems and total down time of 22 big game guzzlers evaluated from 1978-1988 in southern California.

	Type of Problem						
Guzzler	Freeze	Design	Float Valve	Natural Disaster	Other	Total Failures	Total Down Time (Months)
Clark	0	1	2	0	1	4	46
Kelso	0	0	0	0	1	1	0
Kingston	3	2	1	0	2	8	12
Chemhuevi	0	0	0	0	0	0	0
Old Dad	1	0	2	0	1	4	8
Clipper	0	2	1	0	2	5	20
Piute	5	0	0	0	1	6	18
Sheep Camp	0	0	2	0	2	4	15
Surveyor	0	1	1	0	1	3	3
Old Woman	1	0	2	0	2	5	0
S I-40	6	1	3	1	0	11	24
N I-40	0	0	0	0	0	0	0
Red Cave	1	0	2	0	2	5	12
Cady	4	1	1	0	1	7	17
Blue	0	0	2	0	1	3	7
Dolomite	0	1	1	1	0	3	114
Nopah	4	0	1	0	0	5	14
Last Chance	2	0	2	3	0	7	6
Dry Mtn.	5	0	3	0	1	9	7
Pyramid	3	0	2	0	1	6	17
Weavernoy	0	0	2	0	2	4	6
Chuckwalla	0	0	1	1	2	4	35
Totals	35	9	31	6	17	98	381
Mean	1.6	0.4	1.4	0.2	0.7	4.4	17.3
SD	2.0	0.7	0.9	0.7	0.7	2.6	24.5
Range	0-6	0-2	0-3	0-3	0-2	0-11	0-114

Valves and fittings seem especially vulnerable to freeze-damage. Initially, several drinkers were located up to 150 feet from the storage tanks, creating a need for numerous fittings. Subsequently, those drinkers were moved much closer to the storage tanks, reducing the number of fittings per pipeline. We recommend that pipeline lengths be kept to a minimum in order to decrease the total length of pipe requiring insulation, as well as the total number of fittings required. Additionally, all pipelines and fittings connecting drinkers to tanks should be of 19 mm material. Furthermore, experience has shown that quality of material does matter; use the best fittings, particularly valves, that can be obtained.

Table 2. Big game guzzler inspection and maintenance reports filed by CDFG personnel, members of the Volunteer Desert Water and Wildlife Survey, and other agency personnel, 1978-1988.

Source	Period 1978-1984	Period 1985-1988
CDFG	436 (88.1%)	97 (47.8%)
VDWWS	48 (9.7%)	102 (50.2%)
Other*	11 (2.2%)	4 (2.0%)
Total	**495 (100.0%)**	**203 (100.0%)**

* 14 of the 15 reports filed by other agency personnel were filed by employees of the Bureau of Land Management; 1 was filed by a National Park Service employee.

Float Valves. A total of 31 (31.6%) float-valve-related problems were encountered; these previously had been reported to be significant problems for our big game guzzlers (Bleich and Weaver 1983). Float valves failed for several reasons. They became jammed in the open position, they became jammed in the closed position and, commonly, the float rod merely deteriorated as a result of chemical reactions. The latter problem was corrected by replacing galvanized float rods with rods made of brass.

No float-valves were found frozen, probably because the drinkers in use for the 11-year period were designed so that the float-valve was submerged at all times. This feature also contributed to the lack of problems associated with mineral deposits on the moving parts of the valves.

Design Problems. Nine (9.2%) of the mechanical failures encountered reflected problems with the initial design or construction of the big game guzzlers. In four cases, pipe-fittings were not properly tightened at the time of installation and resulted in leaky or disconnected fittings at a later date. This problem can be eliminated by careful supervision of volunteer construction crews and a close final inspection prior to departing the construction site.

In two cases the surface area from which guzzlers collected water was insufficient in size to allow the tanks to fill, given the low amounts of rainfall characteristic of the two sites. One was corrected by channeling more water, from an additional slick-rock area, to the storage tanks, and the second was corrected with the installation of an artificial apron constructed of hypalon (Water Saver Company, Denver, Colorado). In another case, the guzzler simply was constructed at the wrong location.

The remaining design problems involved a long pipeline, with little fall, that consistently developed air-locks, and the use of an improper storage tank which allowed sediment continually to enter the drinker line, resulting in float-valve problems.

Natural Disasters. Six (6.1%) big game guzzlers were damaged by natural events. In one instance, a pipeline washed out where it crossed a wash, and in another case the concrete dam and 150 feet of associated pick-up pipe were destroyed. One guzzler suffered damage when water floated the (as yet) empty storage tanks from their concrete foundation. Another guzzler washed out completely on two separate occasions. Finally, that same guzzler was severely damaged by a falling boulder, necessitating replacement of one tank.

Although natural disasters do pose a problem, we attempted to minimize their chances of causing adverse affects. During intense thundershowers, desert canyon become raging torrents, and water levels may rise to the elevation at which the guzzler is located. We located the guzzler as far from the bottom of the canyon as possible, but the terrain in which the majority of the catchments are located severely limits available construction sites. Little can be done to prevent damage from falling boulders.

Other Problems. Seventeen (17.4%) of the problems encountered primarily involved the decomposition of metal tanks. Galvanized metal tanks at seven guzzlers required replacement between 1978 and 1988; some of those tanks had been in service since 1971. The average length of time metal tanks were in service prior to replacement as 7.4 years (± 2.3 years). In all cases the cause of failure for metal tanks was rust, which resulted in pin-hole leaks that became progressively larger with time and were impossible to repair. Metal tanks were replaced with commercially available 6,500 liter plastic tanks.

Additionally, at least four metal drinkers rusted out and required replacement. In five other cases, the pick-up screen located on the upper side of the gully-plug became so badly corroded that water could not flow through it into the storage tanks, and replacement was necessary. In one case a fence was damaged by persons unknown, presumably to allow livestock access to the water source.

Overall, 22 big game guzzlers were functional for 86.9% of the 2,904 guzzler months included in this evaluation. One guzzler accounted for 114 of the 381 months of down time; the average down time was 17.3 months (± 24.5 months) (Table 1). Given the complexity of these systems, it is not surprising that the average guzzler was in service for only 87% of its total potential service time; that value likely reflects the great effort put forth in a regular inspection and maintenance program.

From 1978-1984 CDFG personnel performed the vast majority of guzzler inspections and maintenance; from 1985-1988 volunteers have performed about 50% of the inspections. Cutbacks in CDFG manpower will require additional volunteer assistance to insure that inspections continue in a timely fashion and to insure that proper maintenance is performed as needed.

CONCLUSIONS

The overall performance of 22 big game guzzlers constructed for mountain sheep from 1971-1977 has been very good, based on evaluations conducted from 1978-1988. Of the five problem areas identified, one would have been completely eliminated by more care during the planning and construction phase. Problems with freezing will always exist, but can be minimized by using quality construction materials and a regular maintenance program. When metal tanks and drinkers are used, rusting will be a problem, but the use of plastic and/or fiberglass materials for these items could eliminate that problem in the future. (Some problems will, however, be encountered with the effects of ultra violet radiation on plastic tanks; recent evidence of such damage is available, but further discussion is beyond the scope of this paper). Natural disasters will always present potential problems, but careful planning will minimize their effects. Float-valve related problems can be minimized by using float-rods of appropriate material and by insuring that foreign material cannot jam the valves themselves.

The participation of volunteers will become more and more important, as CDFG budget constraints become more severe. Currently, a total of 56 big game guzzlers exist in California, 50% of which were constructed between 1979 and 1987. The continuing outstanding contributions by members of the Volunteer Desert Water and Wildlife Survey, particularly the Area Captain Program, must continue. The fact that from 1985-1988 these persons filed over 50% of the inspection reports, as opposed to approximately 10% of those filed from 1978-1984, attests to their willingness to support CDFG and its desert water development program.

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WATER MANAGEMENT ON CABEZA PRIETA AND KOFA NATIONAL WILDLIFE REFUGES

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ABSTRACT

During the 50 year history of the Cabeza Prieta and Kofa National Wildlife Refuges water development for wildlife has been a major concern. A variety of methods have been used including improvement of natural springs and catchments, rehabilitation of wells and windmills, and building dams and charcos. This paper discusses the different types of water facilities of the two refuges, the methods used in their development and the varying success of each.

INTRODUCTION

Cabeza Prieta Game Range (860,000 ac.) and Kofa Game Range (660,000 ac.) were established in 1939 to protect areas within the Sonoran Desert of southwestern Arizona. From 1939 to 1975 they were managed jointly by the Fish and Wildlife Service (FWS) and the Bureau of Land Management (BLM). Since 1976, the FWS has managed these areas independently as Cabeza Prieta National Wildlife Refuge (CPNWR) and Kofa National Wildlife Refuge (KNWR).

Management on CPNWR is primarily concerned with desert bighorn (Ovis canadensis mexicana), Sonoran pronghorn (Antilopcapra americana sonoriensis), and migratory birds. Mule deer (Odocoileus hemionus) and javelina (Tayassu tajacu) occur at low densities on CPNWR. Management on KNWR is most concerned with desert bighorn, mule deer, migratory birds, and game birds.

Historically, both areas were used by miners and livestock operators. Grazing was phased-out by 1983. Limited mining occurs on both refuges. Mining was suspended on 90% of CPNWR when the military withdrew the area in 1941. Since then, CPNWR has been overlaid by the Luke Air Force Base Gunnery Range (renamed the Barry M. Goldwater Gunnery Range in 1986). Mineral entry on KNWR was withdrawn in October 1988.

As a result of air-to-air military training over CPNWR public use is allowed only by permit. KNWR allows open public access under typical FWS regulations. Early water developments within both refuges were for human and livestock survival (travelers, miners, livestock operators). Because water was considered to be the prominent limiting factor, early wildlife water developments (1940s and 1950s) were intended to improve desert bighorn habitat (Halloran and Deming 1958). Recently, KNWR managers have developed waters to aid in management of mule deer, desert bighorn, other wildlife, and control of feral burros. Recent managers on CPNWR have been concerned with water development as it relates to habitat(s) of Sonoran pronghorn and desert bighorn.

This paper summarizes 50 years of water management on CPNWR and KNWR. Unless we state otherwise, information contained was extracted from unpublished refuge files. We acknowledge the following groups and agencies for their participation in water management on CPNWR and KNWR: U.S. Air Force, U.S. Marines, Arizona Desert Bighorn Sheep Society, Arizona Game and Fish Department, Civilian Conservation Corps, Youth Conservation Corps, Yuma Valley Rod & Gun Club, and various individual volunteers.

STUDY AREA

Basin and Range topography characterize CPNWR and KNWR. Within CPNWR, seven mountain ranges (i.e., Growler, Granite, Agua Dulce, Bryan, Mohawk, Sierra Pinta, and Cabeza Prieta mountains) provide the majority of bighorn habitat. These ranges resulted from faulting which produced mesa-type and sierra-type mountains which trend northwest to southeast (Simmons 1966). The valleys between these mountain ranges are habitat for Sonoran pronghorn.

Topography of KNWR is dominated by two large mountain ranges (Kofa and Castle Dome) and the wide alluvial King Valley. Portions of four smaller mountain ranges (South Plomosa, New Water, Little Horn, and Tank Mountains) intrude into the area.

The climate of both areas is governed by a bimodal precipitation pattern (i.e., summer and winter rainfall). Summer precipitation results from convectional storms associated with air currents from the Gulf of Mexico. Winter rains are produced by Pacific storm fronts. Summer temperatures are commonly above 100° F, whereas winter temperatures are seldom below freezing.

CPNWR and KNWR are within the Lower Colorado River Valley and Arizona Upland subdivisions of the Sonoran Desert Biome (Turner and Brown 1982). The following plants are ubiquitous through out the refuges and may be predominant in certain areas. Creosote bush (Larrea tridenta) and bursage (Ambrosia spp.) are predominant in most valley floors. Washes within valley floors and canyons are typified by paloverde (Cercidium spp.), mesquite (Prosopis spp.), and iron wood (Olneya tesota). Bajadas are typically dominated by saguaro (Cereus giganteus), ocotillo (Fouguieria splendens), brittle bush (Encelia farinosa) and cholla cactus (Opuntia spp.). Unlike CPNWR, jojoba (Simmondsia chinensis) is common on KNWR. Several annual grasses and forbs also become apparent during and after summer and winter rains.

METHODS

Springs

Agua Dulce Spring has been an historic perennial water on CPNWR. We improved it in 1951 by clearing alluvial debris and constructing a small concrete dam to increase its water storage capacity. In 1961 and 1986, we again maintained Agua Dulce Spring by removing debris from years of drainage.

KNWR manages 11 springs (Alamo, Budweiser, Covered Well, Dixon, High Tank 2, 8, and 9, Indian Seep, Jasper, Holly Seep, and Tunnel). Some of these have been shaded to reduce evaporation and fenced to exclude feral livestock (see Helvie 1971). In one case (Budweiser Spring), KNWR constructed a masoned-rock grotto cover and retaining wall to protect the Spring box from run-off and direct sunlight. In some cases water from these springs is piped to a drinker.

Natural Catchments

Natural catchments occur within CPNWR (Sheep Tinajas Altas and Tule tanks) and KNWR (Bandy, Cripple, Hanging, Ladder, Lower Arch, Red, and Robin tanks) in localities that are remote or near dependable waters. Early refuge managers developed watershed catchments to increase water availability. We may develop these areas if we determine that wildlife habitat would be enhanced.

Improved Natural Catchments

CPNWR and KNWR improved several natural catchments (CPNWR-- Buckhorn, Cabeza Prieta, Eagle, and Heart tanks; KNWR-- Black, Blue Rock, Cereus, Chain, Charlie Died, Chuckwalla, Drill Hole, Figueroa, Frenchman, Hidden Valley, High Tank 3, 6 and 7, Hollow Rock, Horse, Little White, McPherson, Modesti, Moonshine, Red Hill, Saguaro, Salton, Squaw, and Yaqui tanks). Managers selected areas that had ephemeral (i.e., water for < 1 month) or intermittent (i.e. water for > 1 month and < 1 year) waters. We located silt trap dams upslope in the natural path that water flowed to a catchment area. These silt traps were designed like a standard retention wall and constructed of concrete or rubble- rock masonry. We installed a metal pipe at the bottom of silt traps to provide a conduit for water seepage to the catchment.

Below the silt trap, we enlarged the catchment area by blasting and/or constructing a lip-like concrete dam at the edge of the catchment. Managers on KNWR improved some natural catchments by shading with tin roofs and fencing with livestock enclosures (see Helvie 1971). We typically sealed the catchment area with a coat of Acryl 60, followed by a coat of thoroseal, and finished with Acryl 60. These catchments can hold 4,000 to 10,000 gallons of water.

In some cases we constructed a ramp for wildlife access to water. Before these modifications, wildlife sometimes became trapped and died when water levels were low. At Chain Tank, the manager of KNWR constructed a tunnel through bedrock to allow bighorn to escape.

Periodically we use hand tools and buckets to remove debris that have accumulated in silt traps and catchment areas. In some cases, we use heavy equipment if the catchments are accessible. Where the concrete or bedrock cracks, we reseal the catchment and silt traps as they were when first constructed.

Man-made Rock-Concrete Catchments

Managers constructed man-made catchments to improve bighorn habitat. (CPNWR: Bassarisc, Buck Peak, Halfway, Granite, North Pinta, Senita, and Tuseral; KNWR: Cereus, High Tank 7, Little White, Saguaro). The design of these catchments allowed water storage from a natural watershed.

Large holes (approximately 10 ft. X 10 ft. X 20 ft.) were blasted in the bedrock. As with improved natural catchments, we constructed a silt trap upstream. Around some of these catchments a 1 to 2 ft. high perforated rock wall was constructed (held together with masonry). This design slowed water velocity and allowed filtration into the catchment. We constructed tin sunshades over these catchments to reduce evaporation.

Wells

Wells originally developed for livestock or mining use are maintained by CPNWR (Adobe, Bluebird, Charlie Bell, Chico Shuni, Little Tule, Papago, and Tule) and KNWR (Adams, Craven, De La Osa, HooDoo, King, Mid, New Water, Scotts, Wilbanks, and 12 Mile). Most wells are pumped by standard Aermotor windmills, whereas a few others are operated by pumping jack.

KNWR windmills pump water into two 600 gallon storage tanks. When storage tanks are full, a return pipe channels excess water back to the well. Water flows from the storage tanks to a 350 gallon ground-level drinker that provides wildlife with natural access. Water level of these drinkers is regulated by a float valve. KNWR managers have shaded most of their drinkers by tin sunshades to reduce evaporation and fenced to exclude livestock (see Helvie 1971).

CPNWR wells are similar to those on KNWR, but we lack tin sunshades and do not need livestock exclosure. On CPNWR, we experimented with solar charged pumping jacks on 3 wells (Bluebird, Chico Shuni, and Jack's). For this design, a 500 gallon storage tank is filled from the well and piped to a float regulated drinker. Water level of the storage tank is maintained by a Dayton micro-floatswitch (Grainger Inc, Phoenix AZ) that is connected to a standard automobile (Ford) solenoid. The solenoid is connected to a 12 volt battery (high amperage-low drain RV battery) on one side and a Dayton permanent magnet 1 1/7 H.P. electric motor (Grainger Inc. Phoenix AZ) on the other (L. Williams, CPNWR, pers. comm.). The battery is charged by a Arco 14 volt solar panel. Wiring is standard 14 gauge.

Dams and Charcos

Dams and charcos have been developed on CPNWR (Antelope, Jose Juan, Redtail) and KNWR (Charco 3, Crowder, Crowder 1 and 2, Four Peaks, Geyser, Ketcherside, Kofa, Owl Head, Red Rock) in canyons and valley bottoms. We constructed charcos by landscaping a low area in a valley. We cleared these areas and constructed a dirt tank by cutting and filling. We typically fenced these areas to exclude livestock. On KNWR dams were constructed like a standard concrete retaining wall. Sometimes these dams were constructed using rock masonry.

Parabolic Rain Catchments

On CPNWR, we have experimented with "Range Guzzlers" (Fiber Erectors Inc., Red Bluff, CA) supplied by Luke Air Force Base. These catchments consist of a 2,100 gallon tank (16 ft. diameter) buried to ground level (in 20 in. hole) and covered with a 200 sq. ft. parabolic collector that is bolted directly over the tank. The collector is designed to reduce evaporation and fill the tank after 17 inches of rain. Two wildlife entrances are located at opposite ends of the catchment.

DISCUSSION

Springs

Historically, Agua Dulce Spring on CPNWR produced about 2 gallons/day (Broyles 1988). Heavy storms in the area during the 1980s may have caused the decline of this spring. We plan to remove the debris and construct a retaining wall to protect the spring box. We can not blast in the area for fear of diverting the aquifer.

On KNWR, we have decided not to modify the natural flow of perennial springs. If we attempted to control the spring in order to reduce water waste, we may disrupt the aquifer and cause a decline in the flow.

KNWR managers noted that most of their springs occur at similar elevations. With this information, we can explore areas at these elevations for developments of springs and wells.

Natural Catchments

Availability of water in natural catchments depends on seasonal precipitation, aspect in relation to the sun, and the features of the terrain that allow the catchment to be cleaned of debris during heavy run-off. Because precipitation in this area is localized and variable, some natural catchments may go dry during summer. In the future, we may construct sunshades over such tanks to increase water availability.

Improved Natural Catchments

Several times since their development, improved natural catchments have gone dry and we supplemented them with hauled water. By sealing with Acryl 60 and thoroseal, we seem to increase water availability. Usually resealing and silt removal is required at 5 to 15 year intervals.

At some tanks, we have opted to not remove the debris that has accumulated in silt traps. Removing this debris in certain situations may overly disturb the upslope water-shed which was modified by silt traps.

We have had problems with the design of some improved natural catchments. In such cases, silt traps were not placed correctly and did not protect the catchment area from silt accumulation.

Man-made Rock-Concrete Catchments

In some years these man-made catchments did not receive adequate rainfall to provide water throughout the summer. As a result, we routinely hauled water to catchments that dried during the summer. This was facilitated because these catchments were built in areas with vehicle access.

Initially, some man-made catchments were intended to store water on a bedrock surface. It became evident that water was leaking so we attempted to seal the cracks. Later we constructed concrete walls on the bottom and sides of man-made catchments. Also, we placed tin sunshades over these catchments.

As with improved natural catchments, these catchments require maintenance (silt removal and re-sealing) about every 5 to 15 years.

Wells

Windmill wells require periodic servicing (changing oil and cup leathers). In some cases, mill heads are damaged by strong winds and require repair.

Occasionally, we inspect solar powered wells on CPNWR to check float valves, wiring, batteries, and electric motors. Life expectancy for batteries and solenoids is 2 to 3 years. Electric motors should last 5 to 10 years before overhaul.

Dams and Charcos

Dams and charcos on CPNWR and KNWR have had limited success. Usually when water is available at these locations, water is readily available in many locations and the range condition is favorable. Problems with poor water availability seem to be associated with seepage, high evaporation, and rapid siltation. In one case on KNWR (Kofa Dam), water seeps downslope and resurfaces. In some cases, areas adjacent to charcos are invaded by thick brush stands which may lead to reduced water use by ungulates.

Parabolic Rain Catchments

We found that "Range Guzzlers" are inadequate for CPNWR. Within CPNWR, 5 to 10 inches of annual rainfall falls short of the 17 inches required to fill the 2,100 gallon storage tank. This design is practical if we intend to haul water to an area or the collection surface and storage capacity allowed the catchment to be self-sustaining.

WATER MANAGEMENT PHILOSOPHIES AND CONCLUSIONS

The evolution of water management on CPNWR and KNWR began when both areas were managed as one complex (from 1939 to 1979). Since 1939, KNWR has been more active than CPNWR in terms of water development. This was mostly the result of CPNWR being less accessibledue to the military withdrawal and the notion that CPNWR had less potential to produce wildlife. On both areas, the most aggressive water development occurred in the 1940s and 1950s. The primary objective during this period was to develop waters to improve bighorn habitat.

As generations of managers cycled through these areas, each was determined to match or surpass the improvements of their predecessor(s). As a result, water developments were intended to improve the habitat(s) of other wildlife (i.e., mule deer, 12 Sonoran pronghorn, migratory birds, and game birds). This trend continued through the 1980s.

Recently, managers have become concerned with the potential of developing waters to the extent that wildlife populations and range conditions could be threatened. As a result, we have set a slower pace for water development. Because wildlife production is related to several environmental parameters, our current philosophy is concerned with wildlife distribution in relation to waters, the effects water development might have on population dynamics and range conditions, and the effects water development could have on wildlife tradition and use of particular areas.

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A METHODOLOGY FOR ESTIMATION OF WATER USE (CONSUMPTION AND EVAPORATION) AT WILDLIFE WATER DEVELOPMENTS

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Abstract

In an attempt to justify quantities of water to claim when filing water rights on wildlife water developments in Arizona, a methodology which estimates wildlife consumption and evaporation losses from natural and man-made water sources (excluding lotic systems) was developed. Based on Local precipitation levels, big game herbivore densities and movements, their water consumption rates and perceived watering behaviors, and other factors, the method attempts to provide objective estimates of water use by wildlife. Because of gaps in knowledge of the dynamics of these site-specific behaviors, the model inherently includes a number of untested assumptions, inferences and generalizations, and does not and likely cannot attain complete objectivity. Field verification is required for assumptions used in the technique.

INTRODUCTION

Arizona Revised Statutes state that "the waters of all sources, flowing in streams, canyons, ravines or other natural channels, or in definite underground channels, whether perennial, intermittent [or] flood,. . . and of lakes, ponds and springs on the surface, belong to the public and are subject to appropriation. . ." (A.R.S. 45-141.A). Although this definition apparently excludes water catchments which intercept rainfall prior to entering natural channel, it does encompass small retention dams, tinajas, spring developments, etc., which the Arizona Game and Fish Department (AGFD) has interest in protecting and developing for wildlife purposes.

The water rights application process entails among other things, quantifying water use for a given purpose (e.g. domestic, irrigation, wildlife, etc.) prior to issuance of a Certificate of Water Right. Prior to 1986, AGFD more or less arbitrarily chose quantities to claim when filing for water rights for wildlife use. Continued increased demand for Arizona's limited water supplies compelled the Department to devise a more legally defensible method of quantifying water use for wildlife purposes in the event of court challenges to our claims.

The procedures described below are intended as a framework from which AGFD can justify quantities of water to claim for wildlife purposes when filing for water rights with the State of Arizona. The method attempts to provide objective estimates of the amounts of water consumed by wildlife and lost through evaporation at non-instream surface water sources (and certain groundwater developments). Because of inadequate knowledge of the dynamics of wildlife watering patterns, the method inherently includes a number of inferences and generalizations, and is based on inadequately validated assumptions. Final estimates of water use obtained from the method therefore cannot be considered as absolute quantifications for a given water or year, but rather approximations based on the limited data available.

The model is empirically based, and at this stage of our knowledge, is intended to approximate the range of responses (water use) possible. We also expect the model to stimulate a more complete investigation and understanding of the process interactions, and hope additional research on the subject will be forthcoming. Although we have not tested the model's accuracy, it nevertheless provides a consistent methodology for quantifying wildlife water use for legal claims.

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THE METHOD

I. SURFACE AREA AND STORAGE VOLUME OF THE WATER SOURCE

Estimation of the surface area of the water body to be claimed is necessary to establish how much evaporation can be expected in a given year, and is determined by multiplying its mean width by mean length at full capacity. Storage volume of the water source is important to establish how much water is available for consumption and evaporation, and is determined by the product of mean width, mean length, and mean depth.

II. ESTIMATION OF EVAPORATION

Evaporative losses were determined by applying the procedure of Cooley (1970). An average annual evaporation from open water surfaces of 72.4 inches is used as a baseline, which is then corrected by regional adjustment factors (Figure 1). The corrected value is then multiplied by the surface area of the storage site, and converted to gallons per year. Cooley (1970) reports that results will generally be within 10 percent of actual evaporation on an annual basis.

For convenience and simplification of field measurements, the surface area determined at full storage capacity is used in calculation of evaporation, although realistically the area at mean or model storage level should be used. In addition, water is assumed to be present and thus exposed to evaporation 365 days per year. This is certainly true for spring developments which exhibit perennial flow, and is likely for most other developments which divert ephemeral surface flows based on observation and the fact that most

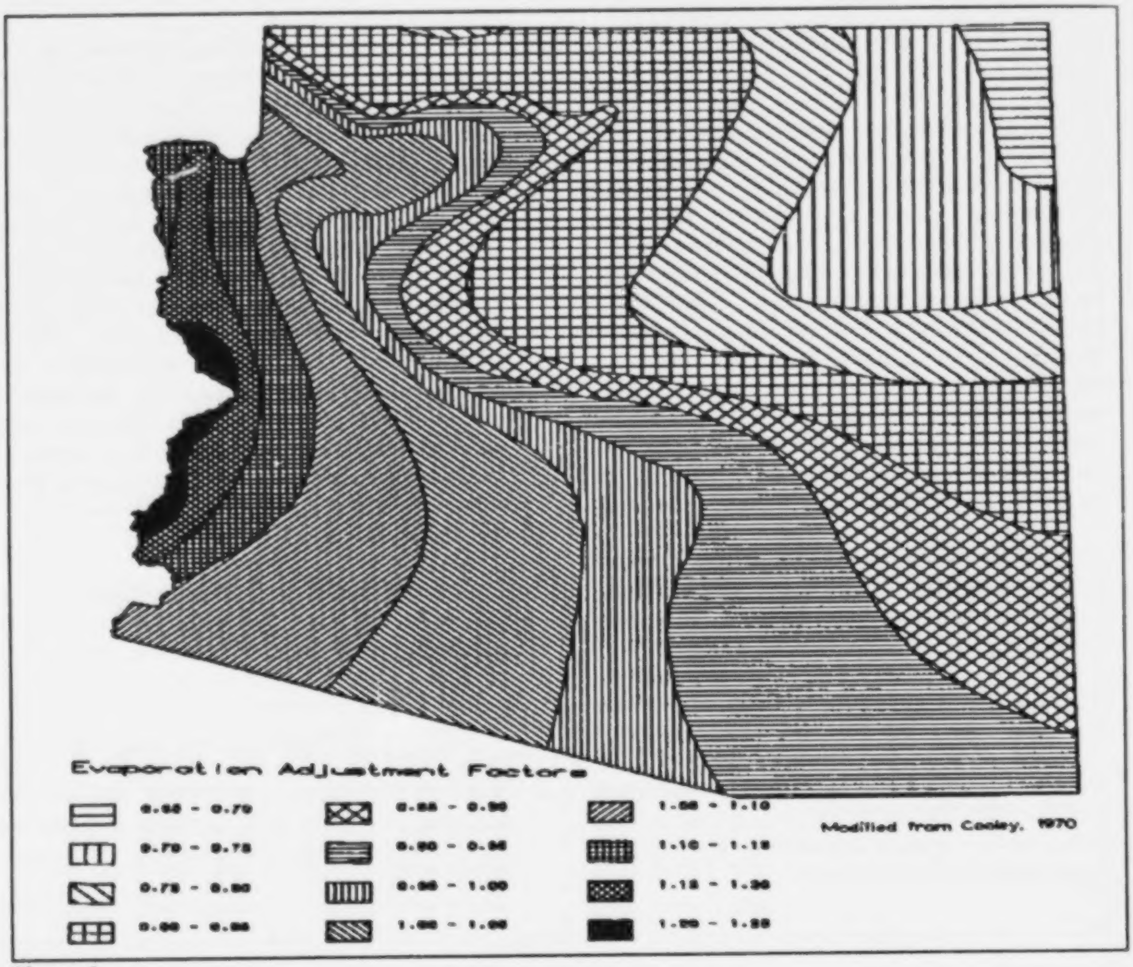

Figure 1.

exposed to evaporation 365 days per year. This is certainly true for spring developments which exhibit perennial flow, and is likely for most other developments which divert ephemeral surface flows based on observation and the fact that most storage sites are constructed with relatively low surface:volume ratios, minimal losses to seepage (bedrock bottoms), and in some cases, enclosed storage tanks and screened roofs. Evaporation from known ephemeral sites can be adjusted accordingly is necessary. Effects of shading, wind and other factors on evaporation are not accounted for in the model.

III. ESTIMATION OF WILDLIFE CONSUMPTION

A. Big Game Herbivores -- Review of the scant literature concerning quantitative aspects of wildlife watering patterns immediately narrowed the scope of any detailed analysis to the big game herbivores---in Arizona these include bighorn

Table 1. Home range and territory sizes of big game herbivores used in calculations (equation 1) of wildlife water use in Arizona.

SPECIES	AREA OF USE (mi^2)	REFERENCES
Mule Deer	3.0	Clark (1953), Hanson and McCullough (1955), Swank(1958), Rodgers et al. (1978).
White-tailed Deer	0.5	Henry (1979), Knipe (1977).
Bighorn Sheep	4.0	Wilson (1971), Blong and Pollard (1968).
[a]Pronghorn Antelope	5.0	Wright and deVos (1968), Kitchen (1974), Kitchen and O'Gara (1982), Gregg (1979).
Elk	1.0	Jeffrey (1963), Mackie (1970), Waldrip and Shaw (1979), Franklin and Lieb (1979).
[b]Javelina	1.75	Minnamon (1972), Bigler (1964), Schweinsburg (1971), Day (1977, 1986), Ellisor and Harwell (1979).
Turkey	0.75	Porter (1977), Lewis (1963), Shaw and Smith (1977).

[a] Kitchen and O'Gara (1982) noted a large variation in home range sizes of pronghorn among different populations. The figure used here is a compromise between typically small home ranges reported outside Arizona and the exceptionally large home range of the Sonoran pronghorn in southwestern Arizona reported by Wright and deVos (1986).

[b] Day (1986) states that 2-3 herds typically utilize permanent waters as common territorial boundaries, each sharing the common source for consumptive purposes. Thus, the expected territory size of a herd of javelina (1.75 mi^2) was multiplied by 2.5 to account for multiple herd use.

sheep, mule deer, white-tailed deer, pronghorn antelope, elk, javelina, and turkey. During rainy periods of the year, these species derive the bulk of their water needs from pre-formed water in the vegetation and other foods they consume (Leopold 1933, Anderson 1949, Elder 1956, Krausman 1976), and thus do not require large volumes of free water.

During more arid periods, however, dehydration of vegetation and increased physiological demand compel them to increase their intake of free water (Clark 1953, Wood et al. 1979, Hervert 1985). As ephemeral water sources begin disappearing in the dry seasons, big game herbivores are forced to frequent increasingly rare remaining sources to obtain their water needs. Herbivore densities thus increase in the vicinity of remaining water sources during these times, increasing the number of animals served by these sources (except javelina; see Table I).

In an attempt to simulate these seasonal changes in watering behavior associated with changes in water availability, the method assumes these behaviors vary according to levels and patterns of precipitation. The state was therefore partitioned into precipitation zones to appropriately scale the length of the critical dry seasons which require more frequent watering by big game herbivores (Figure 2). Waters in arid areas receiving less than 10 inches of precipitation annually were allocated 180 days of dry season herbivore use based on approximations from the literature, unpublished reports, and observations. Waters in more mesic areas of 10-15 inches of annual precipitation were expected to receive approximately 120 days of critical dry season use, and wetter environments receiving

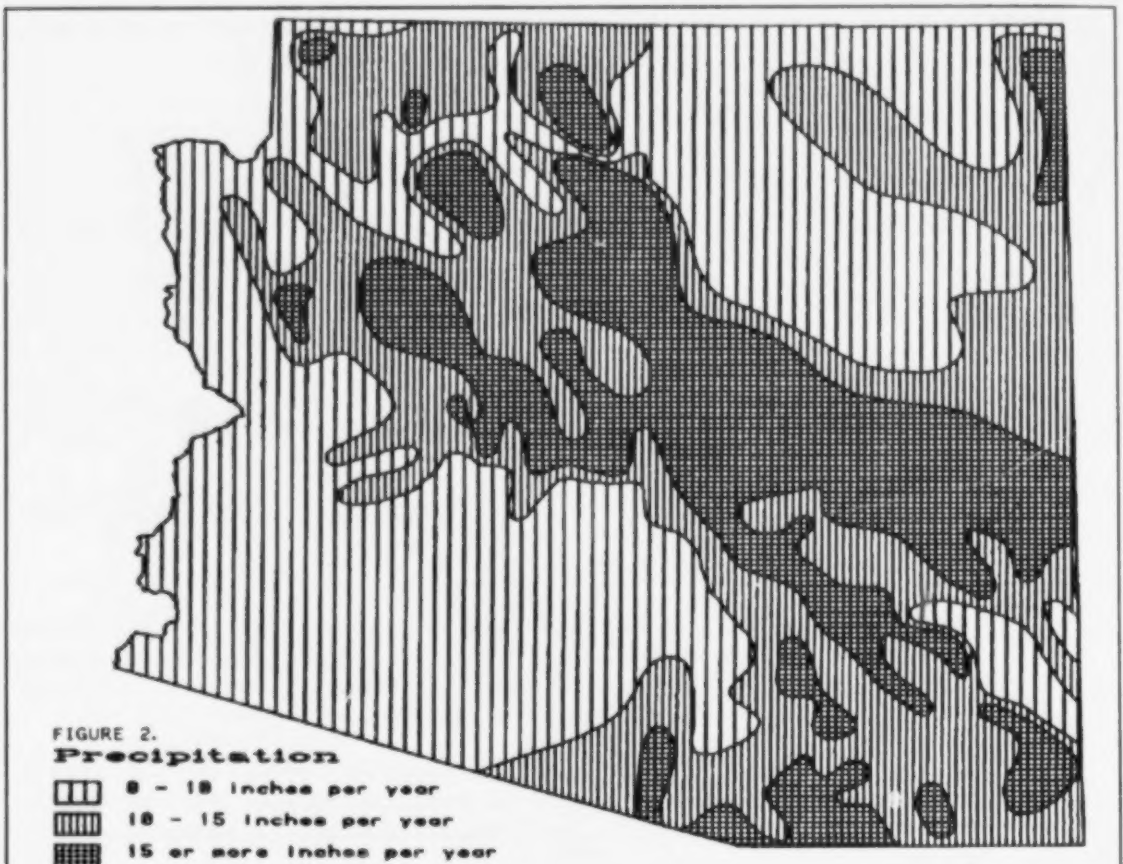

FIGURE 2.

Precipitation

Modified from Sellers and Hill, 1974

Figure 2.

more than 15 inches of precipitation were assigned 90 days of dry season use. The method does not further attempt to account for local conditions of vegetation, water quality, topography, density of water sources, temporal variation of precipitation, etc.

The method addresses five variables which can be combined (multiplied) to provide an estimate of the annual volume of water consumed by big game herbivores at a given water source. The equation is expressed as:

$$\sum_{i=1}^{n} (d-A-q-t)_i$$

where **d** is the "year-round" density of species **i**, **A** is the approximate area normally inhabited by individuals of species i surrounding a water source, **q** is the estimated quantity of water consumed per drinking event by an individual of species **i**, and **t** is the number of days per year an individual of species i is expected to drink free water.

Quantity **t** is further defined according to:

$$t=[f(i)-c]+[f(m)]$$

where **f** = the frequency of drinking events by individuals of species i during the wet **(m)** and dry **(1)** seasons of the year (defined above), and c = the dry season density concentration factor.

"Year-round" densities of big game herbivores in the area of use (d) were taken from AGFD distribution maps (e.g. Figure 3), which are based on field survey and other data. The median values of the ranges exemplified in Figure 3 were chosen to represent modal conditions.

Sizes of the geographic areas serving big game herbivore species around a water source (A) were selected from averaged territory and home range estimates reported in the literature, using studies from Arizona when possible (Table 1). These measures were chosen in lieu of a "cruising radius", a term occasionally referred to in the literature indicating the maximum distance an individual will be found from water during the dry seasons. Cruising radius values are not always available, are usually related to a species reported home range size, and may not accurately reflect a species' movements during wetter periods of the year.

The estimated quantity of water consumed each drinking event (q) by individual big game herbivores were obtained primarily from literature values of summer consumption in desert areas of the southwest (Table 2).

The frequency of drinking events (f) of big game herbivores during wet (m) and dry (1) seasons were based in part on the limited literature references available on the subject. There is considerable variation in the reported frequency of drinking events for these species during dry summer months, but most references in Table 2 and elsewhere report values in the range of once every 1-3 days depending on time since last rainfall, ambient temperatures, animal life history variables, and other factors. A mean frequency of once every two days was selected as representative of these species' watering habits on average during the dry seasons.

Scattered references suggest consumption of free water by big game herbivores during wetter seasons may be once every one or two weeks. A value of once every 10 days was chosen to represent this frequency during wet seasons for all herbivore species. Table 3 lists values of the number of days per season an herbivore is expected to drink free water.

The potential density increase (c) of big game herbivores around water during dry periods of the year is the most difficult variable to objectively evaluate in the model. No quantitative estimates are available to our knowledge, and the complex interactions among animal density, precipitation, density of permanent waters, and other factors render attempts at generalization difficult to verify. A number for which there are some quantitative estimates available and which biologists can at least evaluate with some experience, however, is the number of big game herbivores utilizing a given water source on a regular basis during the dry seasons.

The mean number of mule deer and javelina watering per night at waterholes in the Tucson Mountains (10-15 inches of annual precipitation) reported by Elder (1956) ranged from one or fewer in December to near 60 in July for each species. Annual means were 15.1 for mule deer and 13.9 for javelina. These numbers may be overstated somewhat since some individuals may have watered more than once per night. Other Arizona waterhole counts provided by the U.S. Fish and Wildlife Service for these and other big gameherbivores generally confirm these values as typical for arid areas.

Density concentration factors were derived at by initially accepting a potential range of values the numbers of animals of a species utilizing a water source on a regular basis (N) could exhibit. The ranges chosen assumed that waters occurring in higher animal density classes would receive greater levels of use. Then a potential set of density concentration factors were assigned to each species' density classes, assuming greater density concentrations would occur in areas of lower initial animal density. The mathematical relationship between the density concentration factors (c) and N are defined according to:

$$N = d * A * c$$

where **d** and **A** are as defined in equation (1).

Concentration factors were iterated until an acceptable range of N was achieved, and final estimates of water use (consumption and evaporation) by all species (including "other" species; see section III.B) approximated or were less than the expected volume of water available to the water source on a yearly basis. For example, a development which diverts ephemeralsurface flows in a part of the state receiving less than 10 inches of rainfall per year could not have consumption and evaporation which exceeded approximately four times its storage volume, since it would be unlikely that it would fill more than four times per year.

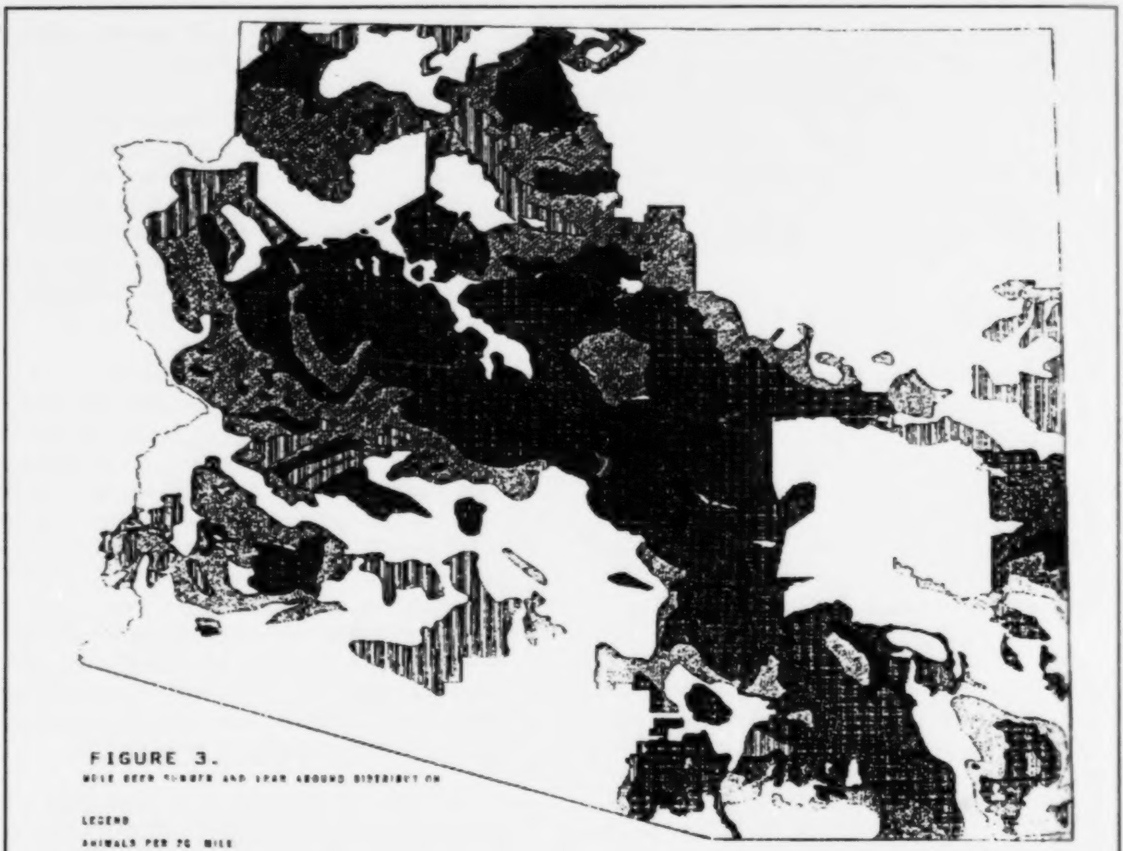

Figure 3.

Table 2. Daily consumption rates of big game herbivores used in calculations (equation 1) of wildlife water use in Arizona.

SPECIES	CONSUMPTION (Gallon)	REFERENCES
Mule Deer	1.5	Elder (1954), Hervert (1985).
White-tailed Deer	1.0	Nichol (1938).
Bighorn Sheep	1.5	Turner (1970), Hailey (1967), Knudsen (1963).
Pronghorn Antelope	1.0	Beale and Smith (1970), Beale and Holmgren (1974), Yoakum (1980), Sundstrom (1968).
Elk	2.0	*Estimated based on body size.
Javelina	0.5	*Estimated based on body size.
Turkey	0.25	*Estimated based on body size.

Table 4 lists animal density categories, and associated set of dry season density concentration factors and numbers of animals utilizing a water source on a regular basis during the dry season. It should be stressed that the density concentration factors were only used in calculations of dry season water consumption, and that N does not enter into equation (1) directly.

Shown in Table 5 are the resulting wet and dry seasonal consumption values for given herbivore density classes in different precipitation zones of the state derived from equation (1). They reflect the assumptions that (1) free water consumption is increased with increasing densities of animals, and (2) consumption is decreased in areas of higher annual precipitation or shorter dry seasons.

B. Consumption by Other Species -- The lack of detailed literature on free water consumption by other species forced a more subjective estimation procedure for this aspect of a claim. Data on feral honey bees in Arizona provided by the Carl Hayden Bee Research Center in Tucson and other sources indicate a potential annual volume of water use (consumption and thermoregulation) of more than 4000 gallons by colonies within a 3 mile cruising radius of an unlimited water supply (Taber 1979, Erickson 1986). Although such levels of water use are unlikely for isolated waters of the type typically claimed by AGFD, the potential exists for losses of hundreds, if not thousands of gallons per year via honey bees and other native hymenopterons.

Water consumption by dove and quail must also be significant at many sites. These gregarious species typically drink twice daily, and waters may receive use by scores or more individuals per day (Elder 1956). Consumption by other less-studied species such as mammalian predators, nongame birds, amphibians, etc., is generally unquantified but potentially great. Abundance of all these species is assumed to be at least generally correlated with abundance of big game, and therefore for lack of a better method, a standard of the final big game herbivore consumption estimate was added to incorporate their potential consumption. Based on a consensus of biologists contacted in the review process for this model, 50% of the herbivore consumption estimate was allocated for consumption by other species.

Table 3. Estimated number of days big game herbivores are expected to drink free water during wet (m) and dry (l) seasons of the year in different precipitation zones of Arizona (equation 2).

	Number of Days	
Precipitation Zone(Inches/Year)	Wet Seasons (m)	Dry Seasons (l)
0 - 10	18.5	90
10 - 15	24.5	60
15 +	27.5	45

IV. ESTIMATION OF THE TOTAL VOLUME OF WATER USE AT A SITE

The total claim of water use for wildlife purposes at a site was estimated from totals of losses to evaporation (Section II) and wildlife consumption (Section III). In order to avoid duplication of wildlife consumption at a site with multiple impoundments which are claimed separately, the total consumptive value at a site was adjusted (multiplied) by the relative storage capacity of each impoundment. An example of the quantification procedure for Dead Deer Tank in La Paz County, Arizona, is provided on a standardized worksheet in Table 6. This worksheet is submitted along with other documentation in support of a water right claim.

DISCUSSION AND CONCLUSIONS

Inspection of Table 5 reveals an as yet unstated and untested assumption which is integral to the model, and indeed to wildlife water development programs in general: Larger density categories of animals are indicative of better habitat conditions which are less limited by water supplies. This assumption was stated in a slightly different manner in a previous section: Lower density concentration factors occur in higher animal density categories. Thus, although more animals are expected to use a given water source in areas of high animal density, their dry season density concentrations around that water are smaller compared with areas of lesser animal density. This is assumed because of a greater density of available water, and thus animals do not have to travel as far to reach them.

Some of the values in Table 5 are unrealistic in that, for example, mule deer densities of 21-35 animals per square mile in areas receiving less than 10 inches of precipitation annually will likely never occur. The site specificity of the model, however, assures that this artifact will not affect consumption estimated at any given site.

As previously stated, this model has not been validated in any manner other than that predicted consumption should not in most cases exceed the expected amount of water available for consumption in an "average" year. Although actual consumption levels are not known, the model is believed to at least be realistic in this feature. Since the animal density concentration factors were determined with this control as a primary consideration, final estimates of expected consumption may in many cases be a maximum estimate. This attribute of the model is probably desirable without more direct knowledge of actual consumption in that it can allow for increases in animal populations (with associated increased consumption) without having to modify water rights claims.

In conclusion, the model presented above was developed to provide a consistent, explainable methodology to arrive at an estimate of water use at remote wildlife water developments for legal water rights claims. Although somewhat simplistic, it attempts to mimic perceived big game herbivore watering behaviors, and "objectively" quantify expected water use. Annual and seasonal fluctuations in precipitation and evaporation, variations of local topography and vegetation, and other unquantifiable factors likely render a more refined or realistic approach to the subject difficult. The increasing importance of obtaining water rights for wildlife purposes, however, seems to necessitate this type of approach in order to justify claims for adjudication. We hope the model will stimulate research necessary for its further refinement and validation.

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Table 4. Big game herbivore density categories, estimated dry season density concentration factors, and numbers of individuals drinking free water on a regular basis (N). See text for further explanation; equation 3.

SPECIES	Density Class (no/mi^2)	Density Concentration Factor	N
Bighorn Sheep	0.0 - 0.1	20.0	4.0
	0.1 - 0.5	10.0	12.0
	0.5 - 2.0	5.0	25.0
	2.0 - 5.0	2.5	35.0
	5.0 -15.0	1.25	50.0
Mule Deer	0.25- 0.5	5.0	5.6
	0.5 - 1.0	4.0	9.0
	1.0 - 4.0	3.0	22.5
	4.0 - 7.0	2.0	33.0
	7.0 -10.0	1.5	38.2
	*8.0 -20.0	1.0	42.0
	*21.0 -35.0	1.0	84.0
White-tailed Deer	0.5 - 1.0	10.0	3.8
	1.0 - 3.0	8.0	8.0
	3.0 - 7.0	6.0	15.0
	7.0 -15.0	4.0	22.0
Antelope	0.0 - 0.1	10.0	2.5
	0.1 - 0.5	5.0	7.5
	0.5 - 1.5	2.5	12.5
	1.5 - 2.5	2.0	20.0
	2.5 - 4.0	1.5	24.4
	4.0 - 6.0	1.0	25.0
Elk	0.5 - 1.0	10.0	7.5
	1.0 - 1.5	8.0	10.0
	1.5 - 3.0	6.0	13.5
	3.0 - 5.0	4.0	16.0
	5.0 - 7.0	3.0	18.0
Turkey	0.2 - 0.5	20.0	5.2
	0.5 - 1.0	16.0	9.0
	1.0 - 2.5	12.0	15.8
	2.5 - 5.0	8.0	22.5
Javelina	0.0 - 0.5	5.0	5.5
	0.5 - 1.0	4.0	13.1
	1.0 - 1.5	3.0	16.4
	1.5 - 3.0	2.5	24.5
	3.0 - 4.0	2.0	30.6

*North Kaibab Herd

Table 5. Big game herbivore density categories and associated quantities of wet and dry season water consumption of big game herbivores derived from Equation 1. See text for further explanation.

SPECIES	Density Class (no/mi^2)	Seasonal Consumption (gal)					
		<10/yr.		10-15 in/yr.		+15 in/yr.	
		Dry	Wet	Dry	Wet	Dry	Wet
Bighorn Sheep	0.0 - 0.1	540	6	360	7	270	8
	0.1 - 0.5	1620	33	1080	44	810	50
	0.5 - 2.0	3375	139	2250	184	1688	206
	2.0 - 5.0	4725	388	3150	514	2362	578
	5.0-15.0	6750	1110	4500	1470	3375	1650
Mule Deer	0.25-0.5	759	31	506	41	380	46
	0.5 - 1.0	1215	62	810	83	608	93
	1.0 - 4.0	3038	208	2025	276	1519	309
	4.0 - 7.0	4455	458	2970	606	2228	681
	7.0-10.0	5164	708	3442	937	2582	1052
	*8.0-20.0	5670	1166	3780	1544	2835	1732
	*21.0-35.0	11340	2331	7560	3087	5670	3465
White-tailed Deer	0.5 - 1.0	506	7	338	9	253	10
	1.0 - 3.0	1080	18	720	24	540	28
	3.0 - 7.0	2025	46	1350	61	1012	69
	7.0-15.0	2970	102	1980	135	1485	151
Antelope	0.0 - 0.1	225	5	150	6	112	7
	0.1 - 0.5	675	28	450	37	338	41
	0.5 - 1.5	1125	92	750	122	562	138
	1.5 - 2.5	1800	185	1200	245	900	275
	2.5 - 4.0	2196	301	1464	398	1098	447
	4.0 - 6.0	2250	462	1500	612	1125	688
Elk	0.5 - 1.0	1350	28	900	37	675	41
	1.0 - 1.5	1800	46	1200	61	900	69
	1.5 - 3.0	2430	83	1620	110	1215	124
	3.0 - 5.0	2880	148	1920	196	1440	220
	5.0 - 7.0	3240	222	2160	294	1620	330
Turkey	0.2 - 0.5	118	1	79	2	59	2
	0.5 - 1.0	202	3	135	3	101	4
	1.0 - 2.5	266	6	177	8	133	9
	2.5 - 5.0	506	13	338	17	253	19
Javelina	0.0 - 0.5	246	10	164	13	123	15
	0.5 - 1.0	591	30	394	40	295	45
	1.0 - 1.5	738	51	492	67	369	75
	1.5 - 3.0	1107	91	738	121	554	135
	3.0 - 4.0	1378	142	919	188	689	211

*North Kaibab Herd

Table 6. Example of a completed worksheet used in determination of the annual volume of water use (wildlife consumption and evaporation) at a surface site for water rights claims.

Name of Water:________________________ Drainage:________________
Location:____________________________ Precipitation Zone:____________

I. WILDLIFE CONSUMPTION

A. BIG GAME HERBIVORES

	Density Class (no/mi^2)	Annual Consumption (gal)
Bighorn Sheep		
Mule Deer		
White-tailed Deer		
Antelope		
Elk		
Turkey		
Javelina		

TOTAL =________ gal

B. OTHER SPECIES - 50% of Total A =________ gal

C. RELATIVE STORAGE VOLUME (if mult. pools) =________ %

D. TOTAL ANNUAL WILDLIFE CONSUMPTION-(A+B)C =________ gal

II. EVAPORATION LOSSES

Annual Evaporation Baseline (ft) ________
X Regional Adjustment Factor ________
X Surface Area (ft^2) ________
= Annual Evaporation (ft^3) ________ =________ gal

III. ANNUAL VOLUME OF WATER USE

Wildlife Consumption (gal) ________
+ Evaporation Losses (gal) ________
= Total Annual Claim (gal) ________ =________ ac-ft

IV. STORAGE VOLUME

Mean Length (ft) ________
X Mean Width (ft) ________
X Mean Depth (ft) ________
= Capacity (ft^3) ________ =________ =________ ac-ft

WATERHOLE MANAGEMENT ON THE DESERT NATIONAL WILDLIFE RANGE

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Abstract

The primary habitat management activity on the Desert National Wildlife Range is wildlife water development; the objective being to increase the summer range of desert bighorn sheep (Ovis canadensis nelsoni). Twenty-nine springs have been developed and 21 artificial rain catchments constructed. The catchment design favored for use today is the "slick rock" development consisting of a concrete collection dam, polyethylene storage tanks and float-regulated drinking trough. The refuge bighorn population is stable which is partially attributed to the expanded availability and distribution of water.

INTRODUCTION

Desert National Wildlife Range (DNWR) was established by Executive Order in 1936 as a conservation area for desert bighorn sheep. Pursuant to the Game Range Act of 1966, Public Land Order 4079 reduced the size from approximately 2.2 million acres to its present 1,588,000 acres and gave sole jurisdiction to the U.S. Fish and Wildlife Service. The significance of the latter legislative action was that all of the water rights within DNWR were acquired by the Government and shortly thereafter, grazing privileges and the concomitant use of water by livestock were eliminated.

Topographically, DNWR consists of six different north-south oriented mountain ranges separated by relatively narrow, flat valleys (Figure 1). Mean annual precipitation at Corn Creek Field Station, elevation 2920 ft., is only 4 in. whereas mean annual precipitation at Hayford Peak, elevation 9912 ft., is estimated at over 15 in. Vegetation of the lower elevations is typical of the Mojave Desert with various desert shrub communities i.e. creosote bush and black brush, being predominate. Vegetation of the higher elevations more closely resembles the Great Basin Desert with communities of pinyon-juniper, pine-fir and bristlecone pine occurring.

As is the case within much of the desert bighorn's range, the availability and distribution of water at DNWR is one of the primary limiting factors. The Sheep Range, the largest and highest of the mountain ranges, has the greatest number of perennial springs. The Desert, East Desert and Spotted Ranges have no known springs. One of the Service's primary management objectives at DNWR is to expand the summer range of refuge bighorn by maintaining and improving existing springs and catchments and constructing new wildlife water developments.

Access to water development sites on the refuge is affected not only by the rugged terrain but by land use designations. All but approximately 265,000 acres of DNWR is proposed wilderness. The western 860,000 acres of DNWR is within the Nellis Air Force Range. The refuge's authorization to utilize U.S. Air Force owned and contracted helicopters helps offset some access problems.

METHODS

Spring Developments

Twenty-nine of DNWR's 33 springs have been developed and are being maintained to enhance the availability of water for wildlife. The basic design consists of a spring box connected to a drinking trough with polyethylene pipe (polypipe). Where flows are seasonal or reduced during xeric conditions, enclosed storage tanks with float-regulated troughs (drinkers) have been installed. Most of DNWR's drinkers were

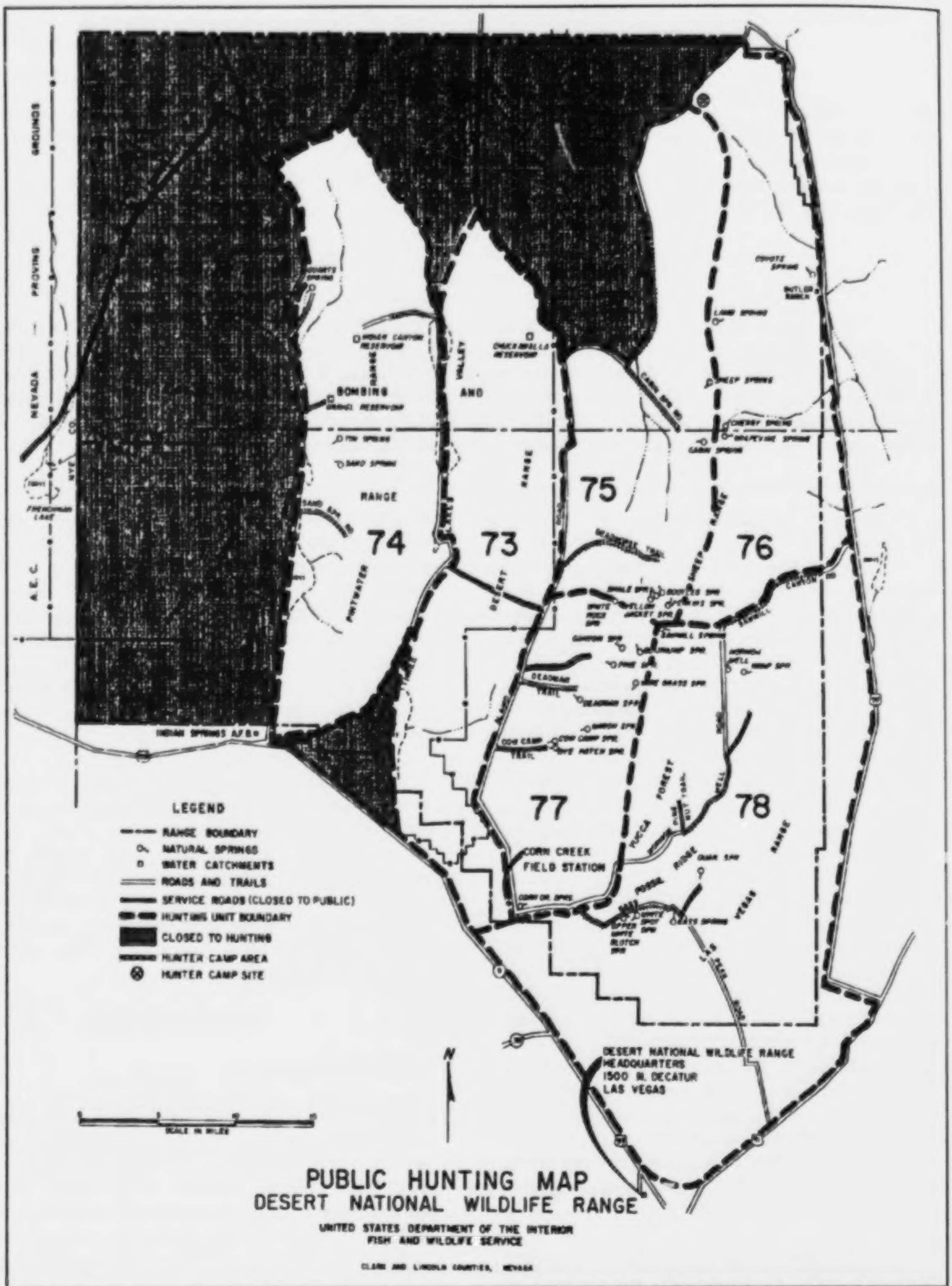
NEVADA PROVING GROUNDS
A.E.C.
BOMBING
RANGE
VALLEY
AND
RANGE
DESERT
SHEEP
RANGE
74
73
75
76
77
78
INDIAN SPRINGS A.F.B.
CORN CREEK
FIELD STATION
YUCCA
FOREST
FOSSIL RIDGE
LAS VEGAS
RANGE
LEGEND
RANGE BOUNDARY
NATURAL SPRINGS
WATER CATCHMENTS
ROADS AND TRAILS
SERVICE ROADS (CLOSED TO PUBLIC)
HUNTING UNIT BOUNDARY
CLOSED TO HUNTING
HUNTER CAMP AREA
HUNTER CAMP SITE
N
DESERT NATIONAL WILDLIFE RANGE
HEADQUARTERS
1500 N. DECATUR
LAS VEGAS
PUBLIC HUNTING MAP
DESERT NATIONAL WILDLIFE RANGE
UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CLARK AND LINCOLN COUNTIES, NEVADA

Figure 1. The location of mountain ranges and water development sites within the Desert National Wildlife Range.

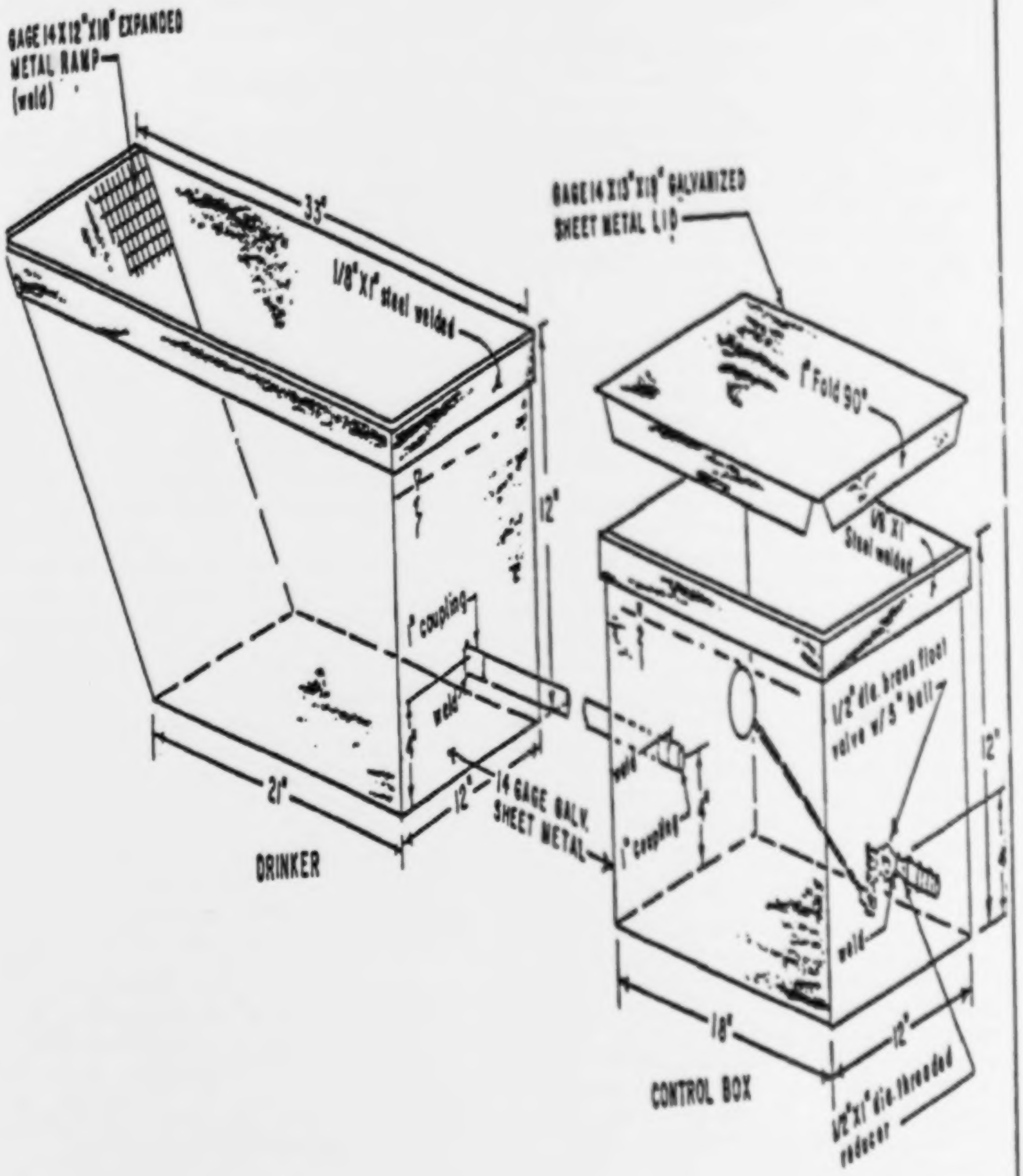
GAGE 14 X 12" X 18" EXPANDED
METAL RAMP
(weld)
33"
1/8" X 1" steel welded
12"
1" coupling
weld
6"
21"
12"
14 GAGE GALV.
SHEET METAL
DRINKER
GAGE 14 X 13" X 19" GALVANIZED
SHEET METAL LID
1" Fold 90°
1/8" X 1"
Steel welded
1/2" dia. brass float
valve w/ 5" ball
12"
4"
weld
1" coupling
6"
18"
12"
CONTROL BOX
1/2" X 1" dia. threaded
reducer

Figure 2. Specifications for a standard float-regulated trough (drawing courtesy of BLM).

constructed in house using 3/8 in. steel plate. More recently, drinkers have been fabricated of galvanized metal by Hammond Sheet Metal of Las Vegas (Figure 2).

Spring boxes have been fabricated from a variety of materials including stone, steel, wood, fiberglass and plastic. Regardless of composition, all are open on the bottom and have porous walls to allow water to enter freely from the surrounding substrate. A removable top keeps out debris while allowing access for cleaning and repair. On some, a filter has been placed over the outlet to reduce the possibility of the line clogging.

At several sites on DNWR water seeps from a vertical rock face. Sand Spring in the Pintwater Range is a good example. Under these circumstances, moisture is collected by placing a container at the base of the cliff.

Our most common type of trough is a steel, porcelain lined bathtub. These were readily available from surplus sources during the years when spring development was at its peak and have proved to be extremely durable. Low profile, galvanized stock tanks have been used at the more recent spring developments.

Polyethylene pipe has, for the most part, made the use of galvanized, steel pipe obsolete because of the ease of handling and installation. Polypipe's expansion-contraction capabilities allow it to withstand freezing temperatures. Both utility grade, 80 PSI, and heavy duty, 160 PSI, polypipe have been used.

An array of enclosed storage tanks have been used at ephemeral springs including aluminum, fiberglass, steel and polyethylene. The polyethylene tanks (polytanks) have been used most recently. Where the small, 500 - 750 gal., aluminum and fiberglass tanks have been used, up to 4 tanks were installed to achieve the desired capacity. The multiple tank storage systems are usually plumbed to act as a single unit.

Natural Catchments

The sedimentary rock, primarily limestone and dolomite, of southern Nevada is not well suited for the formation of water tight "tinajas" or natural catchments. However, there are two tinajas on DNWR that are of some value to desert bighorn. Maintenance at these sites, Heaven's Well and Natural Tank, consists primarily of occasional removal of detritus. Water collection capability at the latter facility has been improved by adding cement curbing.

Man-Made Catchments

Man-made catchments at DNWR are classified as either guzzlers or slick rock developments; the primary distinction between the two being the method by which rain water is collected. The former uses an apron whereas the latter uses a detention dam.

Ten metal aproned guzzlers have been constructed and seven are still in service. The first six were built in the 1960's and two, Quartz and Chuckawalla, eventually received sheep use. Both are located in close proximity to ephemeral waters. Consequently, three of the four metal aproned guzzlers constructed since that period were installed adjacent to existing water sources.

DNWR guzzlers of this type consist of a "V" shaped apron supported by a pipe and/or angle iron frame set in concrete. Each half of the apron has twelve interlocking, galvanized steel panels, 16" wide by 16' long. The panels were supplied by Caine Steel Co., Emeryville, CA. A gutter at the apron's mid-section or apex collects the runoff which is piped off to holding facilities like those described for weak springs (Figure 3).

In 1985 and 1986, four fiberglass guzzlers manufactured by Fiber Erectors, Inc. of Red Bluff, CA were installed. Two were placed in ridge line saddles and 2 on old burns. Sheep use has been documented at 1 of the burn and 1 of the saddle sites. This style of guzzler consists of a 16' diameter trough with a parabolic or dome shaped cover. The cover is slightlysmaller in diameter than the underlying trough and acts as the apron. There are two models, a 990 gal. and a 2100 gal.; the only difference being the shape and depth of the trough. DNWR has two of each.

The rainfall required to fill the smaller and larger units is approximately 8 inches and 17 inches, respectively. For this reason, supplemental aprons were installed at all four (Figure 4). These were constructed by laying 40 mil. polyethylene geomembrane or sheeting on a nearby slope. The supplier for this product was Poly-America Inc. of Grand Prairie, TX. The sheeting is held down by burying the perimeter and placing rocks on the surface area. Water is conveyed to the fiberglass unit via a sump with outflow lines placed beneath and behind the raised lower edge of the apron. Rainfall is kept from running off the sides by dishing out the underlying ground.

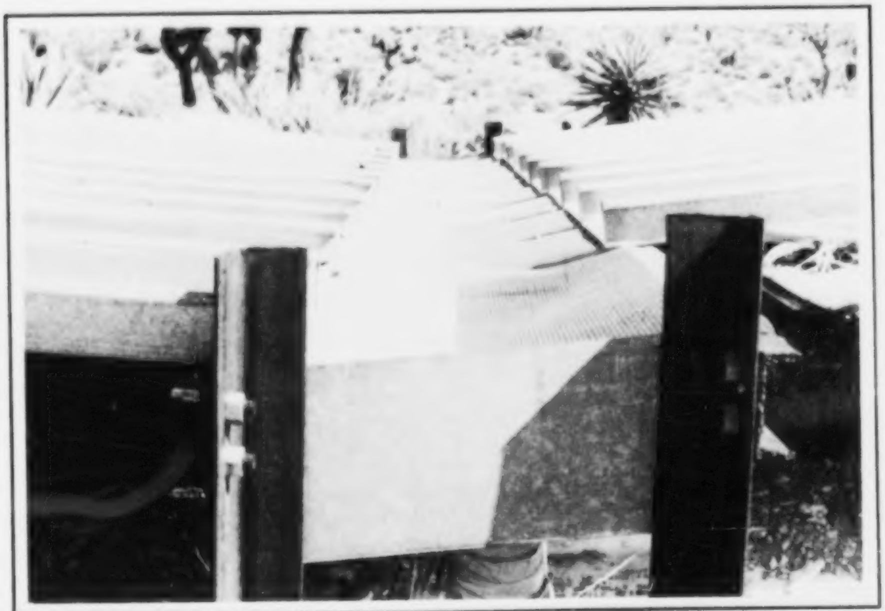

Figure 3. Guzzler with metal apron and central collection gutter.

Three concrete dams were constructed on DNWR during the late "forties" and signaled the refuge's first attempt to expand water distribution through artificial means. Although they were ineffective as storage reservoirs, Gravel Canyon and Indian Canyon dams were successfully converted to slick rock catchments in 1966. This type of development uses a dam as a collection facility and an outlet placed at the base of the dam allows runoff to be piped to holding facilities below. Since 1986, four more slick rock catchments have been constructed in cooperation with the Fraternity of the Desert Bighorn, a Las Vegas based conservation organization. Sheep use has been documented at 4 of the 6 developments.

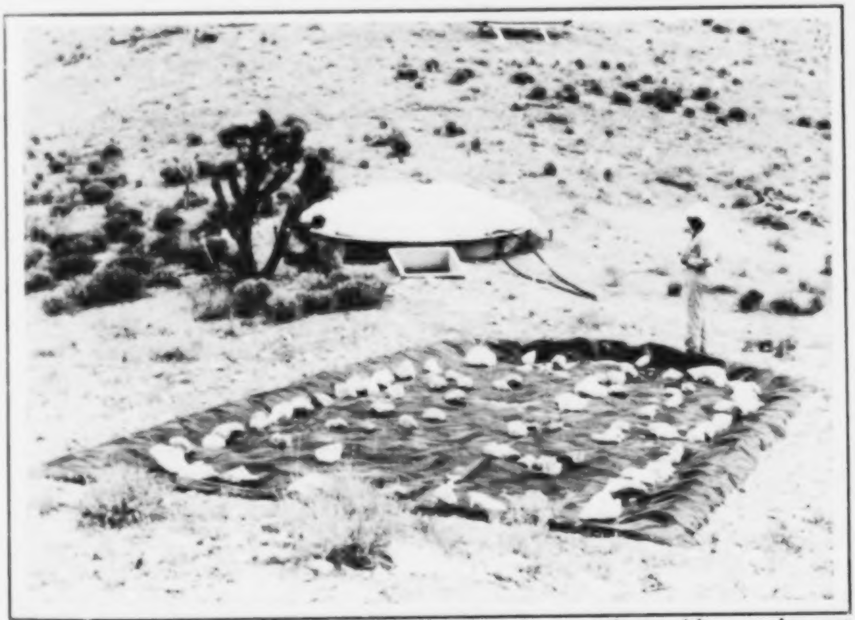

Figure 4. Fiber Erectors guzzler, 2100 gal. capacity, with supplement polyethylene.

This method of collecting rainwater is used extensively for big game water developments elsewhere in southern Nevada and California. Since the conversion of the above dams, the construction of slick rock catchments has evolved significantly. The basic design presently used at DNWR was jointly developed by the Fraternity of the Desert Bighorn, the Nevada Department of Wildlife, the Las Vegas Bureau of Land Management and the U.S. Fish and Wildlife Service and incorporates many of the concepts developed by the

California Desert Bighorn Sheep Society and California Department of Fish and Game.

Site selection is based primarily on the following criteria:

1. A narrow or restricted canyon to keep dam size to a minimum.
2. A watershed composed of bedrock and/or shallow soil to enhance runoff.
3. A level, downhill tank site offset from the canyon floor to reduce the risk of water erosion.
4. A location known to receive some seasonal sheep use to improve the likelihood of bighorn acceptance.

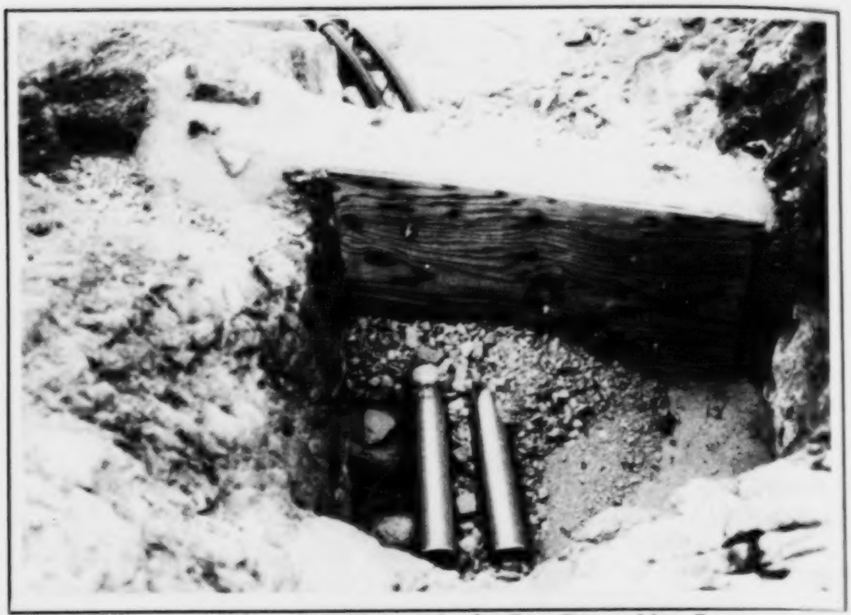

Figure 5. Dam at slick rock catchment in the East Desert Mtn. Range.

Dams are formed using two sheets of 1/2" plywood placed perpendicular to the canyon walls and held together by 18" all-thread bolts (Figure 5). The dam is reinforced with 1" and 1/2" rebar placed in horizontal and vertical adirections, respectively. The ends of the rebar are set in solid rock using a rotohammer. Prior to filling the forms with concrete and rock, 2" galvanized steel pipes with stainless steel well screens on one end and steel, barbed insert fittings on the other are placed thru the forms.

Two 2300 gal., polyethylene water storage tanks are connected to the dam with 2" heavy duty polypipe (110 PSI Drisco pipe). The tanks are painted with outdoor latex to improve longevity and aesthetics. The fill lines are secured to the canyon walls using lead anchors, lag bolts and plumbers tape (Figure 6). The fill lines must also be secured to the tank inlets to prevent them from pulling out.

The tanks are plumbed together near the top in case one of the tanks fills at a faster rate than the other. Both tanks are fitted with overflow lines to prevent erosion of the base by spillage from the manhole covers (Figures 7 and 8). PVC elbows are used at the overflow openings and at any other location where it is necessary to make a sharp bend in the polypipe.

The 1" tank adapters (outlets), at the base of the side walls, are fitted with shut-off and check valves. The latter valve prevents the potential loss of water from a sound tank via back flow into a leaky tank. The metal valves and associated nipples are wrapped with foam or fiberglass insulation to prevent freezing.

The float box and trough are connected to one another and the valve assemblies using steel insert fittings and 1", 160 PSI Drisco pipe. These lines are buried to prevent freezing. Float boxes are constructed from galvanized steel. Drinking troughs are made from the same material or fabricated on site using wire mesh and concrete (Figure 9).

The suppliers for the polytanks, pipe and well screens are listed in the appendix. The other slick rock water development components were purchased locally or custom built to our specifications.

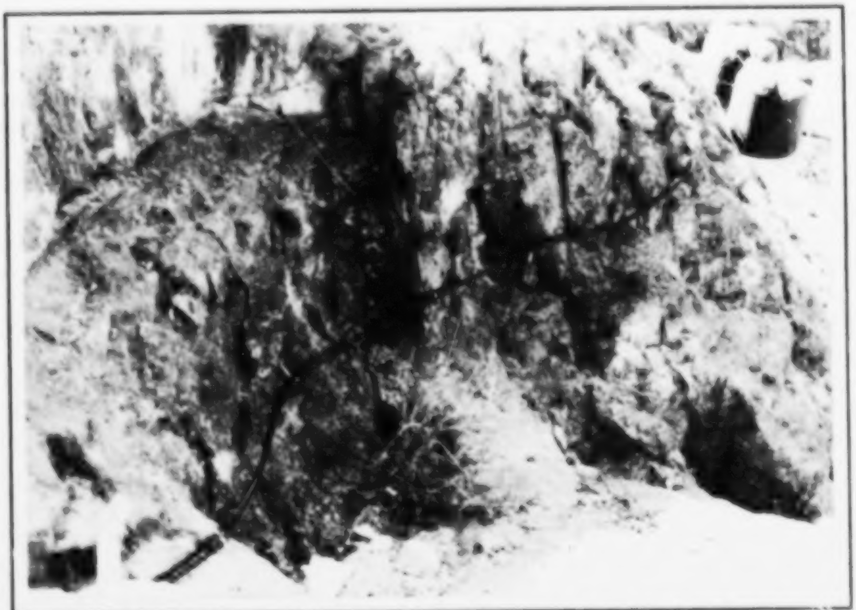

Figure 6. Polyethylene fill lines anchored to canyon wall at slick rock catchment in the East Desert Mtn. Range.

DISCUSSION

Spring Development

The development of DNWR's springs, particularly the installation of storage tanks at the weak and/or intermittent seeps, has made water available to bighorn that would not have otherwise been available during the drought periods. Since all the known springs with wildlife value have been developed, the opportunities to further expand bighorn summer range by this means are limited. There is, however, still some benefit to be derived from upgrading and enlarging the existing facilities.

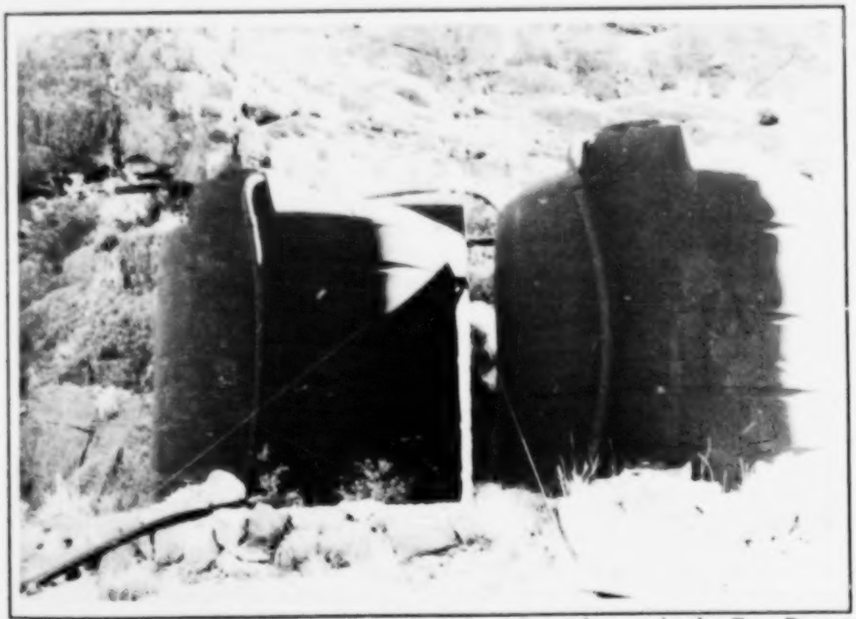

Figure 7. Polyethylene storage tanks at slick rock catchment in the East Desert Mt. Range.

The choice of materials used for the spring boxes, troughs and drinkers has been of little consequence. The use of aluminum storage tanks and utility grade polypipe is a different matter. Heavy duty polypipe should always be used whenever the possibility of freezing exists, particularly at intermittent springs where the ability to hold or put water into storage is dependent upon the integrity of the pipe lines. The aluminum tanks acquired from military excess are totally unreliable because of the corrosive properties of the refuge's alkaline soils and water. Including springs and guzzlers, in excess of 24

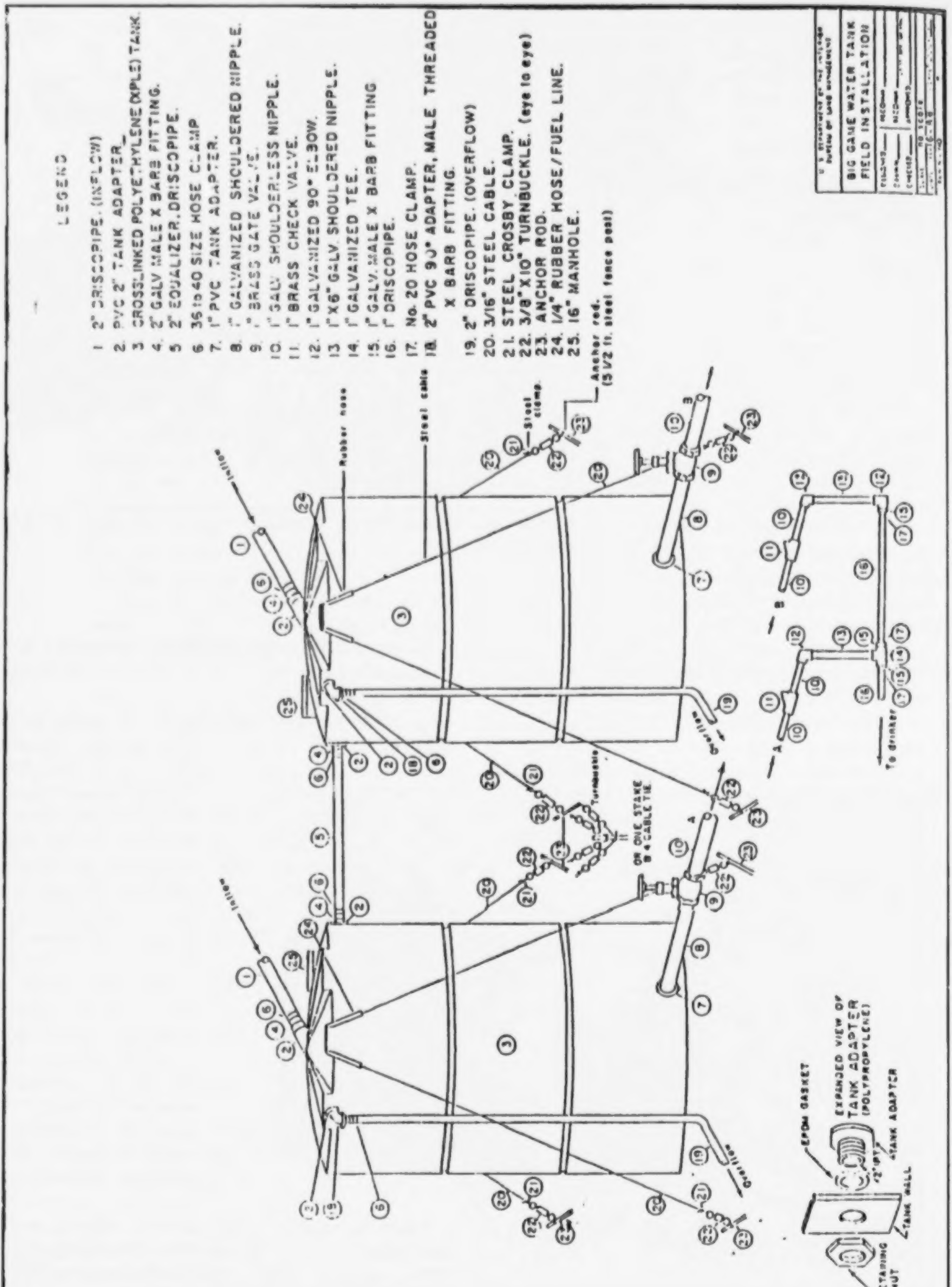
LEGEND
1 2" DRISCOPIPE. (INFLOW)
2. PVC 2" TANK ADAPTER
3 CROSSLINKED POLYETHYLENE (XPLE) TANK.
4. 2" GALV MALE X BARB FITTING.
5 2" EQUALIZER, DRISCOPIPE.
6 36 to 40 SIZE HOSE CLAMP
7. 1" PVC TANK ADAPTER.
8. 1" GALVANIZED SHOULDERED NIPPLE.
9. 1" BRASS GATE VALVE.
10. 1" GALV SHOULDERLESS NIPPLE.
11. 1" BRASS CHECK VALVE.
12. 1" GALVANIZED 90° ELBOW.
13 1"X6" GALV. SHOULDERED NIPPLE.
14. 1" GALVANIZED TEE.
15. 1" GALV. MALE X BARB FITTING
16. 1" DRISCOPIPE.
17. No. 20 HOSE CLAMP.
18. 2" PVC 90° ADAPTER, MALE THREADED X BARB FITTING.
19. 2" DRISCOPIPE. (OVERFLOW)
20. 3/16" STEEL CABLE.
21. STEEL CROSBY CLAMP.
22. 3/8"X10" TURNBUCKLE. (eye to eye)
23. ANCHOR ROD.
24. 1/4" RUBBER HOSE/FUEL LINE.
25. 16" MANHOLE.
Anchor rod. (5 1/2 ft. steel fence post)
Inflow
Rubber hose
Steel cable
Steel clamp
Turnbuckle
OR ONE STAKE W/4 CABLE TIE
Overflow
To drinker
A
B
EPDM GASKET
EXPANDED VIEW OF TANK ADAPTER (POLYPROPYLENE)
TANK ADAPTER
"2" IPT"
TANK WALL
RETAINING NUT
BIG GAME WATER TANK FIELD INSTALLATION

Figure 8. Plumbing system used on slick rock water development storage tanks (Drawing courtesy of BLM).

of these tanks have been removed during the last ten years. Some of the fiberglass tanks have developed minor leaks at the seams and show signs of deterioration where exposed to sunlight. Steel tanks are very reliable but somewhat difficult to handle because of their weight. Although the polytank's life span is yet to be determined, its light weight, puncture resistance, attractive cost and selection of shapes and sizes make it the preferred choice.

Man-Made Catchments

DNWR's metal guzzler aprons are almost totally maintenance free but their relatively small size precludes collecting large quantities of rainfall. Therefore, these developments have performed best when used to supplement an existing water source.

The Fiber Erectors guzzler is easy to airlift and install (3 - 4 mandays) and is adaptable to almost any site. However, given the low annual precipitation in southern Nevada, they are effective primarily as a storage tank for an attached apron. On a cost per gallon basis, it is more efficient to employ a large polyethylene apron in conjunction with polytanks, an approach that has been successfully used in the Arrow Canyon Mountain Range.

Slick rock catchments are considered to be the best type of artificial catchment when suitable construction sites are available within the proposed development area. This type of catchment has several major advantages: 1) it uses the whole drainage as an apron; 2) it is a low maintenance, high capacity development; 3) it is located in the type of terrain where bighorn feel secure; and 4) it blends well with the natural surroundings.

CONCLUSIONS

Helicopter data collected from 1974 to the present indicates that the refuge bighorn population is stable numbering approximately 1500 animals. The Fish & Wildlife Service's development of springs and weak seeps along with the construction of artificial catchments is believed to be an important factor in stabilization of the population. Quantifying the effects of refuge water development on population size is difficult due to the absence of comparable population data for the pre-development period.

Recent advancements in material and construction designs along with the increased availability of helicopter support and volunteer labor has given management the option to develop high capacity, dependable water sources in rugged terrain where the probability of acceptance by bighorn is relatively good. The potential to expand bighorn summer range on DNWR is greatest on the lower, desert shrub covered mountains where water is scarce or totally nonexistent, i.e. Desert, East Desert and Spotted Ranges.

Current plans are to build 2 slick rock catchments on Spotted Range during the late

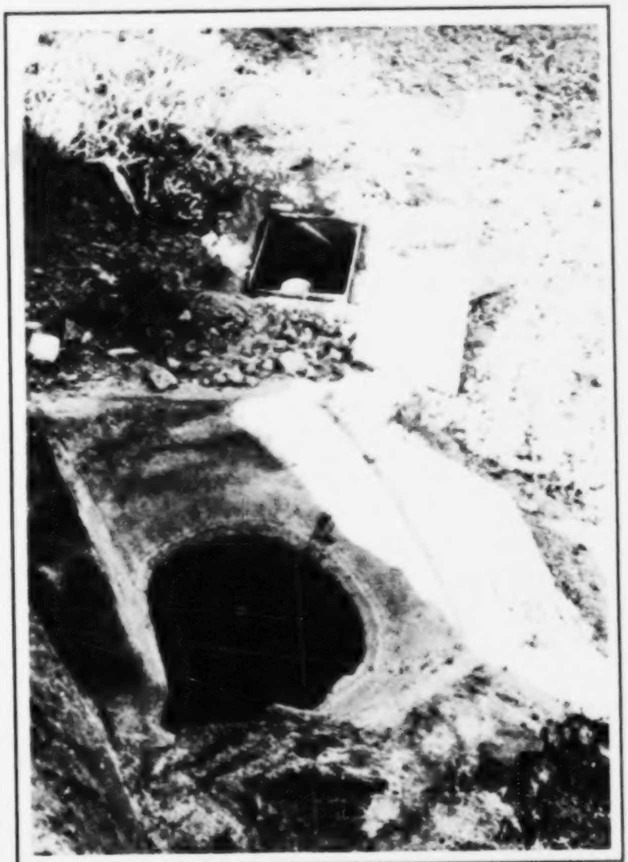

Figure 9. Cement drinking trough with attached float box at slick rock catchment in the East Desert Mt. Range.

winter or early spring of 1989. Maintenance and rehabilitation of the existing developments will also be carried out. Continuation of new catchment construction beyond 1989 is contingent upon funding for material acquisition.

Table 1. Material Suppliers for Slick Rock Water Development Components.

Item	Specifications	Suppliers
* Polytank	STD, Crosslink Resin, Dark Green, 2300 Gallon.	Rotational Molding, Inc. (213) 327-5401
Polytank	STD, Crosslink Resin, Dark Green, 2300 Gallon.	American Storage Tank Co. (209) 439-5189
Polytank	STD, Crosslink Resin, Dark Green, 2300 Gallon.	Terrabella Industries (209) 535-4891
Polytank	STD, Crosslink Resin, Dark Green, 2300 Gallon.	Poly Cal Plastics, Inc. (209) 982-4904
Drisco Pipe	2", SDR 15.5 (110 PSI), 8600, 300' Coil.	Maskell-Robbins Corp. 180 N. Harrison Road Tucson, AZ 85748 (602) 722-0522
Drisco Pipe	1", SDR 11 (160 PSI), 8600. 500' Coil.	Maskell-Robbins Corp. 180 N. Harrison Road Tucson, AZ 85748 (602) 722-0522
Well Screen	Stainless Steel, 2' long x 4" Diameter, 1 Threaded Open End, 5 mm. Intake Openings.	Johnson Division P.O. Box 64118 St. Paul, MN 55164 1-800-328-9891

* All tank suppliers are located in California.

LIMNOLOGICAL FEATURES OF DESERT MOUNTAIN ROCK POOLS

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Abstract

Rock pools (tinajas) in desert mountain ranges of the American Southwest are commonly modified by excavation and damming to provide perennial water sources for wildlife, in particular bighorn sheep. Yet, little attention has been given to water quality of the pools or to the potential effects of engineering modifications on their physical, chemical, and biological characteristics. Limnological investigation of rock pools in central and southwestern Arizona has shown that summer rock pool waters can become highly stagnant, develop blooms of potentially noxious or toxic bluegreen algae and bacteria, evolve harmful reduced substances such as hydrogen sulfide and ammonia, and attain pH levels that are limiting to certain members of the aquatic biota. These conditions may be exacerbated by engineering modifications which increase the depth of pools and prevent normal flushing during freshets. The fact that water quality is most negatively affected during summer is of great importance, because this the time of year when wildlife is both most dependent upon these sources and subjected to greatest physiological stress.

INTRODUCTION

Rock pools comprise a general class of aquatic habitat found wherever natural depressions have been formed in exposed bedrock. These depressions are eroded into bedrock primarily by stream action, wind, and solution processes (Elston 1917, Bryan 1920). Exemplary groups are those found at or near seacoasts (Johnsen 1946, Ganning 1971), on tablelands or plateaus (Bryan 1923) and in streambeds (Elston 1917, Bryan 1925).

A subset of streambed pools constitutes an important, although little studied, type of aquatic habitat in the canyons of desert mountains in the American Southwest. Location of the depressions is dictated primarily by the pattern of geological faults, which is acted upon by fluvial scouring, joint-plucking, and fragmentation (Bryan 1925). These fluvial processes occur when flood waters and their associated bed loads contact irregularities or regions of weakness engendered by fracturing, jointing, or juxtaposition of different rock types varying in hardness. Bryan (1925) identified five types of streambed rock pools--joint-block cavities, scour depressions, riffle hollows, potholes, and plunge pools.

Desert mountain rock pools in the American Southwest, also referred to as rock tanks, potholes, or tinajas (Spanish for bowl or jar), are important natural sources of water for wildlife in this semiarid region (Monson and Sumner 1980, Henry and Sowls 1980, D. Kubly personal observation). However, their small size, coupled with a climatic regime marked by low precipitation and high evaporation, relegates most to the status of ephemeral or intermittent water bodies (Brown and Johnson 1983). The most diminutive, sometimes referred to as tinajitas (Udden 1925), have length and depth dimensions in centimeters, while the largest seldom are more than 10 m long and 5 m deep (Bryan 1925, Tinker 1978).

Wildlife agencies and private organizations have modified many of the larger desert mountain rock pools in order to increase their persistence and predictability as water supplies (Werner 1985). Modifications include removal of sediments, sealing of cracks, shading, and emplacement of dams and upstream gabions. These actions have successfully improved the quantity and distribution of water available to wildlife. Yet, little attention has been given to water quality of the drinking supplies or to the potential effects of these modifications on the physical, chemical, or biological characteristics of the water sources.

This paper is presented to provide information on water quality in desert mountain rock pools to wildlife managers and private organizations concerned with water supplies for desert wildlife. Hopefully, it contains information that can be of use in future decisions on where and how rock pools should be modified when the conclusion is reached to take this action.

Study Area

The study mountains (Figure 1) are part of the horst-graben fault complex that forms most of the north-northwest trending valleys and ranges of the Basin and Range physiographic province (Fenneman 1931). Lithology is dominated by a combination of granites, schists, and gneisses with locally important areas of volcanic extrusions (Bryan 1925).

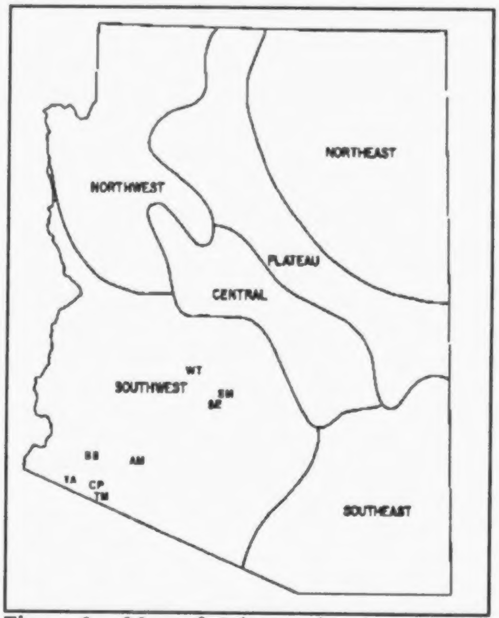

Figure 1. Map of Arizona showing climatic regions and location of mountain ranges from which rock pool samples were collected. (See list of figures for Mtn. Range names).

The mountains lie within the southwest climatic section of Arizona (Sellers and Hill 1974). Mean annual precipitation in the region varies from 19 cm to 28 cm with major, nearly equal, contributions occurring in a bimodal pattern, July-September and December-February. May and June consistently are months of drought, receiving measurable precipitation an average of less than one year in three.

Mean maximum temperatures in the study region vary from 38^{o} C to 40.5^{o} C, while mean minima extend from -0.5^{o} C to 1.7^{o} C. Freezing temperatures can occur from mid-November to March, but diel fluctuations are considerable and associated highs can reach 20 ^{o}C. Prior to the period of summer rainfall, high temperatures are accompanied by daily relative humidities which often fall to 10% or less. This combination produces a June mean pan evaporation of 43 cm in contrast to the much lower mean of 11 cm in January. Annual pan evaporation often exceeds 250 cm, an amount approximately 10X that of annual precipitation.

The majority of observations for this study were made on rock pools in the White Tank Mountains, a relatively small (ca. 175 km^{2} planar area), fault-block range situated in the Lower Sonoran Desert 35 km west of Phoenix, Maricopa County, Arizona (Figure 1, see also Keil 1973). White Tank streambeds contain rock pools whose basins are scoured and polished white in sharp contrast to the pink, gray, and brown surfaces of canyon walls.

The drainage containing the study pools exits the White Tanks to the east through a canyon known locally as Waterfall Canyon. From the entrance to Waterfall Canyon to near the base of the highest summit, the mainstem traverses 6.6 km and ascends from 530 m to 1100 m. The study reach extends up the mainstem 1.3 km, then into its single major tributary for 1.1 km, terminating at 792 m elevation. This ascension is not regular, but rather marked by sharp upgrades interspersed by relatively level stretches. Upgrades are particularly exaggerated at the beginning and terminus of the study reach, which are formed by cliff faces of ca. 20 m and 35 m, respectively.

Within the 2.4 km study reach are some 180 rock pools ranging in depth from less than 10 cm to more than 3 m. Rock pools within the lower 0.8 km lie within a rather narrow, winding canyon having abrupt, steeply sloping to vertical walls extending up to 70 m above the streambed. Pools in this reach are founded in bedrock, and, in some, their sides extend vertically to form canyon walls. Above this mainstream section, the canyon retreats considerably in slope and height. Alluvial, coarse-grained sediments encroach into the streambed, and exposed bedrock surfaces are largely restricted to extruding dikes which form upstream rock pool walls.

The mainstem topography is repeated, although less dramatically, in the tributary reach.

Near its mouth, the tributary breaches a bedrock uplift, forming an abbreviated canyon. Lower pools are arranged in a series of steps scoured in bedrock, but the upper rock pools are founded largely in alluvial material. Beyond the cliff face which marks the interior terminus of the study reach, the drainage enters a broad valley and rock pools diminish in number.

The extensive series of samples from the White Tanks was supplemented by measurements of rock pools, catchments, and cement tanks in or near other mountain ranges in southwestern Arizona (Figure 1). Several of the rock pools have been modified to increase the duration of their water supplies for wildlife. Two of the cement tanks, at Tule Well and Papago Well, are fed by pumped groundwater.

Methods and Materials

White Tank rock pools were numbered by their upstream location in Waterfall Canyon. Seven pools which were sampled consistently are treated in this report. WT2, WT22, WT32, and WT78 are mainstem pools; WT129, WT171, and WT181 are in the tributary.

Morphometric measurements of the seven primary study pools in the White Tanks were made at the initiation of the investigation, and subsequent depth measures were taken from standard locations at each sampling. Pool volumes were calculated by planimetry and depth-volume relationships were estimated using polynomial regression (Dixon 1975). Checks for changes in bottom contours occasionally were made to ensure the continuity of depth-volume relationships.

Alkalinity, pH, dissolved oxygen (DO), and water temperature measurements were made in the field. Alkalinity was determined by titration with 0.02 N H_2SO_4 to phenolphthalein and bromcresol green-methyl red end points. pH was estimated with a Hellige Color Comparator and appropriate indicators. Complementary laboratory measurements with a Beckman pH meter were generally within 0.1 unit of comparator values, although deviations double this amount were encountered in highly colored and alkaline waters. DO and water temperature profiles were measured with a Yellow Springs Co. Model 51 meter.

Water samples for laboratory analyses were collected in 500 ml polyethylene bottles containing two ml of chloroform as preservative. In shallower pools, samples were taken by slowly immersing the containers through the water column. At the deepest White Tanks pool (3.2 m), samples generally were taken with a van Dorn sampler during the period of thermal stratification.

Measurements of conductivity were made immediately after returning from the field with a Hach Chemical Co. conductivity meter. Samples were then filtered through Whatman GF/C filters and refrigerated. Subsequent analyses of calcium, magnesium (from total hardness minus calcium hardness), sulfate, chloride, nitrate-nitrite nitrogen, and soluble reactive (ortho-) phosphate, were performed by appropriate titrametric, turbidimetric, and spectrophotometric methods (Golterman 1969, APHA 1971) using reagents from Hach Chemical Co. All phosphate values were converted to phosphorus by dividing the former by 3.07. Sodium and potassium concentrations were assessed with a Coleman Model 21 flame photometer. Nutrient and major ion analyses were conducted within 24 hours and 2 weeks, respectively, of collection.

Planktonic chlorophyll a determinations were made from samples filtered by hand in the field through Whatman GF/C filters. Pigment extractions were accomplished on sonificated filters held overnight under refrigeration in 95% acetone buffered with magnesium carbonate. Spectrophotometric measurements were made at 663 nm, 645 nm, and 630 nm with the aid of a Bausch and Lomb Model 70 spectrophotometer. Chlorophyll a concentrations were calculated according to the trichromatic equation of Strickland and Parsons (1968).

RESULTS

Rock Pool Morphology

The small size of desert mountain rock pools is exemplified by values of morphometric parameters for seven rock pools sampled most often in the White Tanks (Table 1). Most of the natural depressions in this mountain range, and in others which have been visited, are one meter or less in maximum depth and hold less than 1,500 l of water when full. The deepest

Waterfall Canyon rock pool, WT32, at 320 cm maximum depth has an estimated capacity of 66,400 liters.

Basin and shoreline forms of desert mountain rock pools are somewhat variable, but the effect of erosive action on bedrock by fluvial processes is evident in their morphology. The most common of larger White Tank depressions are plunge pools. They are subconical (D_V seldom greater than 1.5) with the deepest point displaced upstream from the center of the basin (see, e.g. Figure 2). The slope of the upstream face is often near vertical and typically exceeds considerably that of the downstream face. Shore outline is usually regular and subelliptical to subcircular (D_L less than 1.5).

Table 1. Morphometry of selected rock pools in Waterfowl Canyon, White Tank Mountains, Maricopa County, Arizona

l = maximum length; b = maximum breadth; z_M = maximum depth; z = mean depth; A = surface area; V = volume; D_L = shoreline development; and D_V = volume development.

Pool	l (m)	b (m)	z_M (m)	z (m)	A (m^2)	V (m^3)	D_L	D_V
WT2	8.50	4.00	0.92	0.36	20.50	7.40	1.45	1.17
WT22	6.05	2.95	0.83	0.37	12.10	4.45	1.27	1.33
WT32	9.35	7.25	3.20	1.39	48.10	66.40	1.17	1.30
WT78	7.40	4.75	0.99	0.44	24.95	10.95	1.14	1.33
WT129	7.80	4.10	0.95	0.35	17.50	6.20	1.32	1.12
WT171	7.50	4.30	0.80	0.31	19.60	6.10	1.26	1.16
WT181	3.60	2.10	0.78	0.39	3.95	1.55	1.27	1.51

Duration of Existence

Relatively few natural desert mountain rock pools can be considered permanent water bodies. Within the Waterfall Canyon watershed of the White Tank Mountains, only two pools were perennial during the period of observations, October 1974-March 1977 (Figure 3). The most ephemeral existed for less than two weeks during summer without replenishment. Most ephemeral pools were small and well-exposed, but some large pools also lost water rapidly by drainage through cracks in the underlying bedrock. These pools dried quickly regardless of season.

The two perennial pools, WT2 and WT32, owe their sustained existence to different factors. The former is only 92 cm deep when full, but it lies in a highly shaded alcove at the base of a 20 m sheer drop in the lower extreme of Waterfall Canyon. This pool receives seepage from higher levels in the watershed for periods of several weeks following major runoff events, and direct sunlight reaches its surface only for slightly more than one month in the annual cycle. In contrast, the well-exposed WT32 is endowed with perennial status by its considerably greater depth and volume, and by a lack of seepage.

Water Temperature

Surface temperatures in exposed rock pools followed in close synchrony with diel and seasonal cycles of overlying air. Daily increases in White Tank pools ranged from 1-2° C in well protected pools during winter to 13.5° C in a highly exposed, remnant pool in mid-summer. The maximum recorded annual variation was from 3° C to 39.5° C.

Thermal stratification was observed regularly, but there was large variation among days, seasons, and pools in the amount and distribution of heating. Early morning depth profiles were typically homogeneous throughout the year, although occasional examples of minor inverse and normal stratification were measured. Thermal gradients of 3-5° C developed during days of intense heating and little wind, even in pools 40-50 cm in depth. Only in the deepest White Tanks rock pool (WT32) did persistent stratification, occurring over a period of a month or more, occur. Even in this pool, mid-summer to early autumn early morning water columns

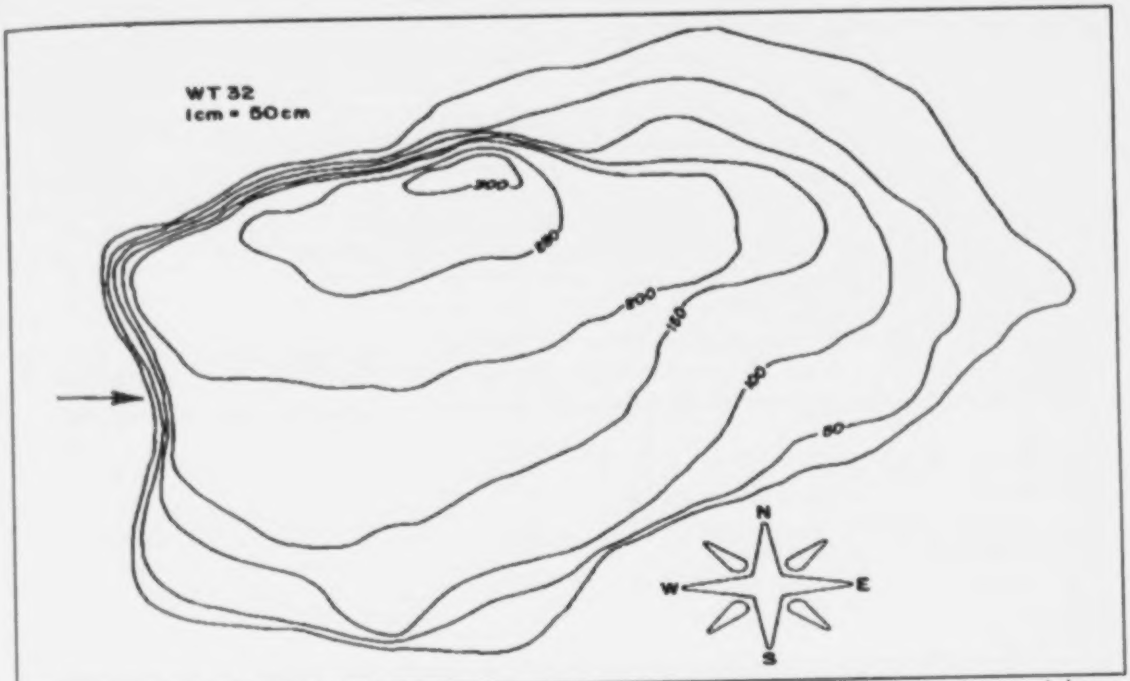

Figure 2. Bathymetric map of rock pool 32, Waterfall Canyon, White Tank Mts., Maricopa County, Arizona. Arrow indicates direction of streamflow.

seldom displayed more than 2° C difference in temperature between surface and bottom levels (Figure 4).

One of the more pronounced examples of thermal stratification in other mountain ranges was observed in the lowest Tinajas Altas rock pool in early October 1978. A temperature range of 31.4° C to 24.9° C occurred in just over 2 m depth at an ambient temperature of 35° C (Table 2).

Dissolved Oxygen

DO levels exhibited marked temporal and spatial variability both within and among White Tank rock pools. The most uniform conditions, both within and among pools, occurred during winter months when low temperatures, limited day length, and low solar angles restricted photosynthetic oxygen production and respiratory depletion. Runoff from winter rains also contributed to more uniform DO concentrations by mixing thermally homogeneous water columns and flushing stagnant waters from the depressions. DO concentrations during this period typically were at 75%-95% of saturation (ca. 7-10 mg/l).

Increasing water temperature, day length, and solar altitude during spring months were accompanied by higher daytime DO concentrations in surface waters and stratification within the water columns. Mid-day values exceeding saturation limits were occasionally observed in more exposed pools by mid-February. These higher concentrations typically were maintained in ephemeral pools until near drying. At this time, DO levels in the remnant pools seldom exceeded 25% of saturation even at mid-day due to accumulated decomposing organic matter and high numbers of respiring heterotrophic organisms. Low DO levels were also recorded in pools partially filled, but not flushed, by summer rains. In these instances, pool waters were murky and stained brown by dissolved organic matter derived from previous autochthonous production and large numbers of drowned terrestrial insects. This condition was sustained for considerable periods in the well-shaded, lower perennial pool, WT2. Early morning DO levels during July and August were typically less than 10% of saturation, and afternoon values seldom increased above 50% of saturation.

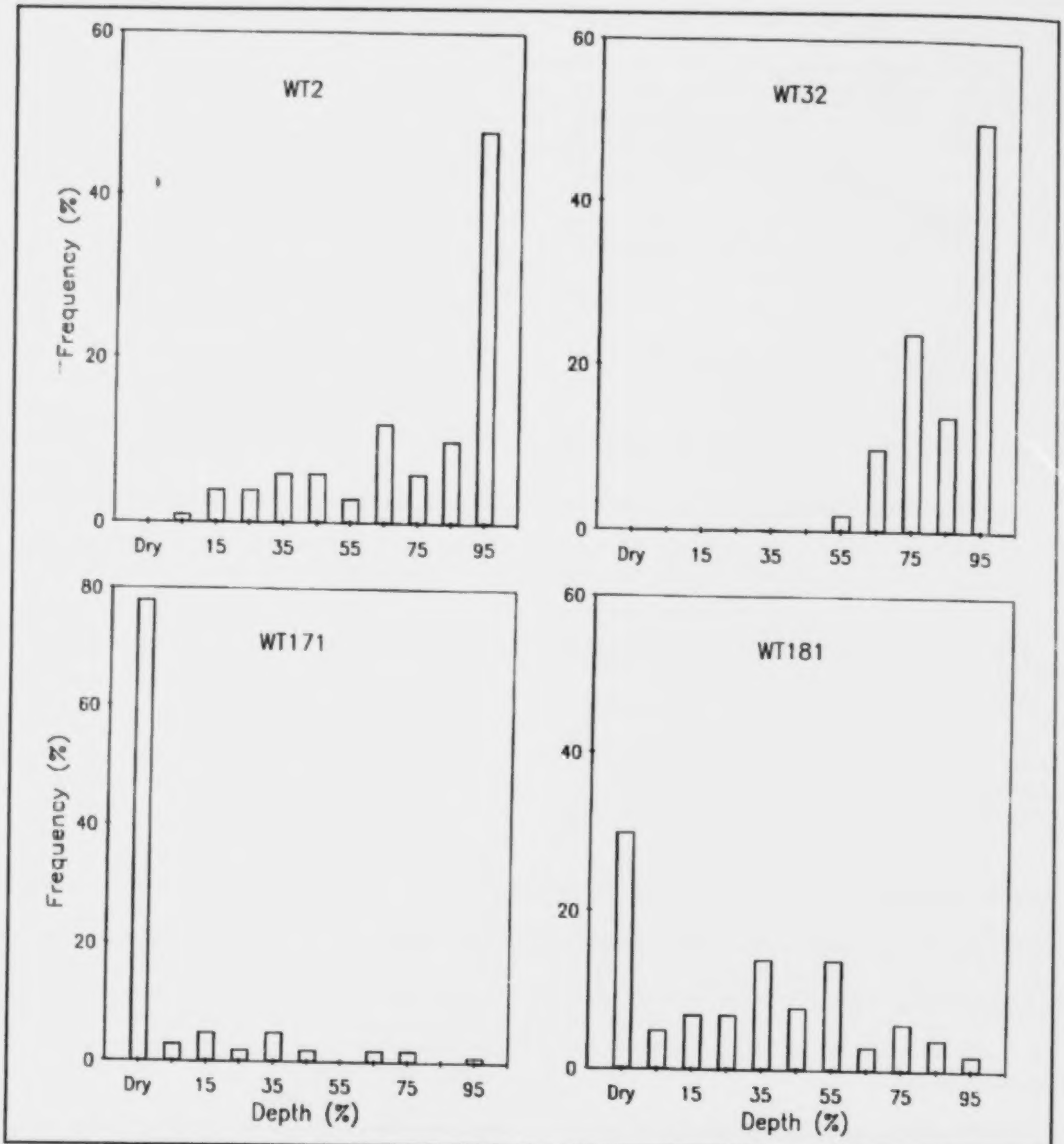

Figure 3. Relative frequency of observed depths (As per cent of maximum)in selected rock pools in Waterfall Canyon, White Tank Mts., Maricopa County, Arizona during the period October 1974-March 1977.

Greatest diel, seasonal, and vertical variation in DO concentrations occurred in the deep perennial pool, WT32. Nearly homogeneous DO distributions were recorded only during three periods: (1) in winter when the water column was nearly homeothermous; (2) for a short time following runoff events sufficient to mix the entire water column, and; (3) early mid-summer to autumn mornings when DO was nearly absent at all levels in the water column. During the latter period, mid-day DO concentrations in near-surface waters reached 14-16 mg/l (200%-225% of saturation), whereas levels below 25 cm in depth remained anoxic (Figure 4).

Ancillary DO measurements in other mountain ranges exhibited a wide variation from nearly anoxic to supersaturated (Table 2). The only pronounced vertical stratification was observed in the lowest Tinajas Altas rock pool. Particularly notable for their extremely low DO concentrations were Buckhorn and Tuseral tanks. In the former, the smell of hydrogen sulfide was evident, and the bottom sediments were black with iron sulfide and decomposing organic matter.

Table 2. Air and water measurements from natural rock pools, modified rock pools, and man-made tanks. Abbreviations for mountain ranges as in Figure 1, those for pools and tanks as in Figure 8.

Pool/Tank	Mtn	Date	Hour	Temperature Air	 H_2O	Cond	DO	pH
Butterfly* (BT)	SE	01-14-78	1130	17.0	12.5		6.8-5.8	7.3
South Mtn 1 (SM1)	SM	02-25-78	1320		24.1	1890		8.3
South Mtn 2	SM	02-25-78	1400		24.3	2590		7.8
Eagle*	AM	03-25-78	1700		19.1	135	10.8	8.6
Thompson**	AM	03-26-78	1230		22.0	145	8.4	8.0
Don Diego* (DD)	AM	03-26-78	1700		20.5	125	13.8	9.4
Baker Butte 1 (BB1)	BB	10-07-78	0730	25.8	21.0	462	1.8	7.5
Baker Butte 2	BB	10-07-78	0815	26.5	23.0	482	1.9	6.8
Tinajas Altas 1 (TA1)	TA	10-07-78	1400	35.0	31.4-24.9	248	10.2-1.0	9.1
Tinajas Altas 2 (TA2)	TA	10-07-78	1435			310		
Tinajas Altas 3	TA	10-07-78	1520			298		
Tule 1 (TU1)	CP	10-08-78	0830	32.5	24.4	675	8.2	7.5
Tule 2 (TU2)	CP	10-08-78	1000	36.0	29.0	210	7.5	8.3
Buckhorn* (BH)	CP	10-08-78	1130	37.0	25.0-23.1	565	0.4-0.1	7.7
Tule Well** (TW)	CP	10-08-78	1400		29.0	6450	13.0	8.5
Tuseral** (TT)	TM	10-08-78	1515	30.9	24.8-24.3	2800	0.8-0.4	8.2
Papago Well**	--	10-09-78	1000	26.5	25.0	985	2.0	

* Modified rock pool, ** Man-made tank or catchment.

pH

Base pH levels in diluted White Tank rock pools following runoff events were circumneutral to slightly alkaline (6.9-7.6) with values typically higher in perennial pools than in ephemeral pools. Highly shaded pools exhibited only moderate pH increases over the course of their existence, whereas pools well exposed to sunlight displayed large diel and seasonal fluctuations. For example, the well protected perennial pool, WT2, had a modal pH of 7.3 and an observed high pH of 8.6. In contrast, the well exposed perennial pool, WT32, exhibited a high pH of 11.0. In the latter pool, diel pH increases from ca. 8-11 were observed during the period of mid-summer to early autumn (Figure 4).

The pH measurements from rock pools and tanks in other mountain ranges varied from 6.8 at Baker Butte to 9.1 at Tinajas Altas (Table 2). Higher values occurred in waters supersaturated with DO and undoubtedly reflect the effects of carbon dioxide uptake during intense photosynthesis.

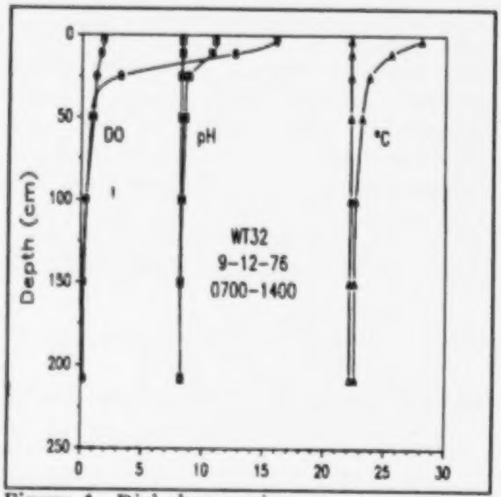

Figure 4. Diel changes in water temperature, dissolved oxygen (DO), and pH in White Tank rock pool 32 on September 12, 1976.

Conductivity and Major Ion Chemistry

Conductivity is a temperature-dependent measure of dissolved minerals and their ion activities. For most fresh waters, conductivity multiplied times a coefficient between 0.55 and 0.75 provides a good approximation of the dissolved solids concentration at 25° C (Hem 1970). Following major precipitation events, dilute White Tank waters had conductivities ranging from 100-150 uS in tributary pools to 175-250 uS in mainstream pools (Figure 5). Subsequent evaporative concentration resulted in increases of from 2-4X runoff levels in most pools, with greater increases generally in permanent pools. The ephemeral mainstream pool, WT78, deviated considerably from this average, however, by increasing to over 13X its initial conductivity (275-3595 uS). No definite reasons for this difference could be determined, but it appeared that this pool received seepage from more concentrated groundwater in addition to surface runoff.

Major ion milliequivalent proportions in diluted White Tanks waters were ranked in decreasing order Ca > Mg > Na > K and HCO_3 > SO_4 > Cl. Only the relationship between Na and K changed to any considerable degree in the progression from upstream to downstream pools. Potassium constituted from 7-10 meq % of cations in upstream tributary pools, but decreased to from 2-4 meq % in lower reaches. This decrease was accompanied by an increase in Na from approximately 15 meq % to 20 meq %.

Temporal variation in major ion proportions was limited in dilute tributary pools, but increased in more concentrated mainstream members. The most marked changes occurred in pools WT2, WT32, and WT78 (Figure 6). Evaporative concentration and subsequent precipitation of less soluble salts contributed to changes in ionic proportions in these pools. Other effects, such as those from the supply of more concentrated groundwater, dissolution of previously precipitated salts by small amounts of runoff, calcite saturation due to carbon dioxide removal during intense photosynthesis, and sulfate reduction under anaerobic conditions were also implicated. Effects of the last two factors were obvious at depth in WT32 in summer and early autumn during the prolonged period of stratification. Sulfate concentration decreased with depth, and the smell of hydrogen sulfide was often apparent during this period. Alkalinity exhibited the opposite relationship with depth (Figure 7).

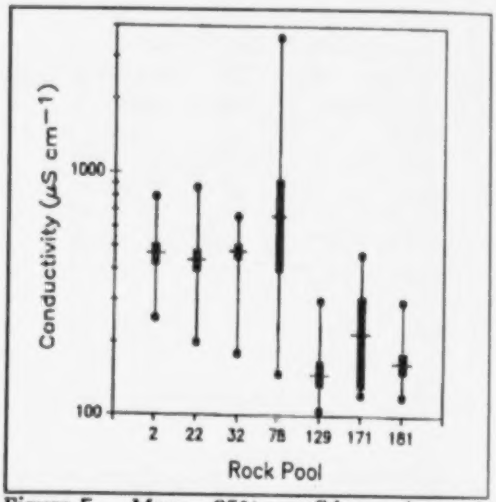

Figure 5. Mean, 95% confidence interval, minimum, and maximum conductivity levels measured in White Tanks rock pools.

Ionic proportions in more dilute waters from other mountain ranges had highest proportions of Ca and HCO_3 as did those in the White Tanks (Table 3, Figure 8). Concentrated waters from Tule Well and South Mountain contained predominantly Na and SO_4. Tuseral Tank water also contained relatively high dissolved solids and had cations dominated by Na, but the three major anions were present in more nearly equal proportions.

Nutrients

Dissolved PO_4-P (orthophosphate-phosphorus, Figure 9) typically exhibited increasing concentrations following runoff events, but highest levels were observed just before drying in ephemeral pools and during summer to early autumn in perennial pools. Minimum dissolved phosphorus concentrations were seldom below the level of detection (0.003 mg l^{-1}).

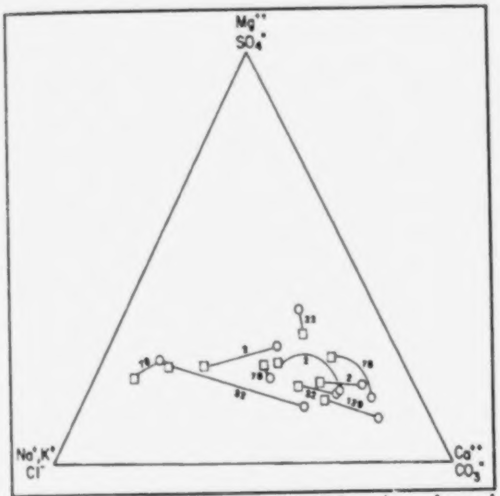

Figure 6. Major ion composition in selected White Tank rock pools. Squares=cations; circles=anions.

Anoxic or near-anoxic conditions were associated with highest dissolved phosphate-phosphorus concentrations, suggesting that internal loading from the sediments was occurring. Summer concentrations in oxygen depleted, highly organic waters of WT2 reached 3.6 mg l^{-1}. Internal loading appeared to contribute to high levels of primary production during summer in WT32. During this period, nocturnal cooling and mixing may have allowed transport of high concentrations of dissolved phosphorus in the lower anoxic zone into surface waters rich in planktonic algae (Figure 7).

Dissolved NO_3-NO_2-N concentrations in White Tank rock pools typically exhibited maximum values in dilute waters received from runoff following precipitation events (Figure 9). Concentrations of 3-5 mg l^{-1} were commonly measured at these times, with little evidence of difference due to position in the watershed. In well-exposed pools, these levels generally fell rapidly, but in highly shaded pools, and particularly in winter, concentrations greater than 1 mg l^{-1} were maintained for more than a month in the absence of any additional input. Concentrations below the level of detection (0.01 mg l^{-1}) were observed in measured pools, typically in summer at low water levels, except for the uppermost two tributary members. The highest tributary pool, WT181, had the greatest mean concentration of NO_3-NO_2-N (2.4 mg l^{-1}), undoubtedly due to its high degree of shading and ephemerality.

Planktonic Chlorophyll a

Mean planktonic chlorophyll a concentrations varied from 2.4 mg m^{-3} in WT22 to 64.0 mg m^{-3} in WT32 (Figure 10). This variation reflected that of maximum values, which ranged from 15.1 mg m^{-3} to 351.2 mg m^{-3} in the same two pools. Minima for all pools, which were measured after major runoff events, were less than 2 mg m^{-3}.

Mid-summer chlorophyll a concentrations in WT32 were highly depth dependent (Figure 7). Near surface levels were often 2.5-3X those at the bottom, and the phytoplankton community was dominated by surface-dwelling blue-green algae

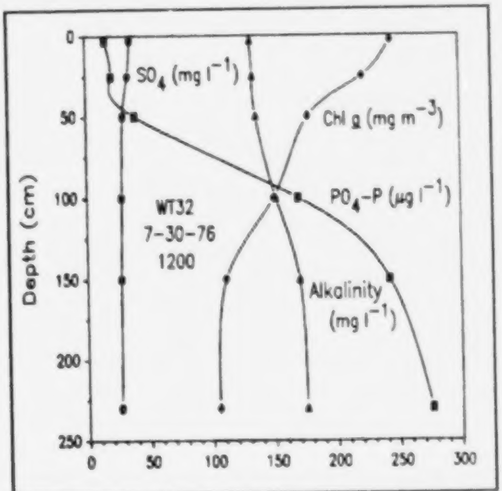

Figure 7. Depth stratification of sulfate, chlorophyll a, orthophosphate-phosphorus, and alaklinity in White tanks rock pool 32 on July 30, 1976. Alkalinity as mg l^4 $CaCO_3$.

Table 3. Major ion chemistry of natural rock pools, modified rock pools, and man-made tanks in mountain ranges of southwestern Arizona. See Figure 1 and Table 2 for locations of pools and tanks.

Pool/Tank	Date	Hour	Na	K	Ca	Mg	Alk	SO_4	Cl
Butterfly* (BT)	02-04-78	1250	1.270	0.517	1.407	0.894	3.00	0.104	0.606
South Mtn 1 (SM1)	02-25-78	1320	13.224	0.087	4.401	1.904	3.80	9.994	4.739
South Mtn 2	02-25-78	1400	19.749	0.312	4.790	3.602	5.88	17.592	5.839
Eagle*	03-25-78	1700	0.165	0.090	1.038	0.240	-.--	-.--	0.203
Thompson**	03-26-78	1230	0.122	0.049	0.399	0.099	-.--	0.094	0.141
Don Diego* (DD)	03-26-78	1700	0.191	0.079	0.878	0.190	0.72	0.333	0.248
Baker Butte 1 (BB1)	10-07-78	0730	0.618	0.220	2.784	0.513	4.20	0.018	0.530
Baker Butte 2	10-07-78	0800	0.557	0.266	3.293	0.613	4.60	0.019	0.457
Tinajas Altas 1 (TA1)	10-07-78	1400	0.287	0.187	1.517	0.356	2.06	0.079	0.502
Tinajas Altas 2 (TA2)	10-07-78	1435	0.639	0.256	1.706	0.497	2.12	0.427	0.649
Tinajas Altas 3	10-07-78	1520	0.357	0.302	1.547	0.546	1.96	0.156	0.480
Tule 1 (TU1)	10-08-78	0830	0.783	0.497	3.593	2.012	5.96	0.018	1.094
Tule 2 (TU2)	10-08-78	1000	0.435	0.205	0.948	0.339	0.96	0.625	0.671
Buckhorn* (BH)	10-08-78	1130	0.505	0.397	2.874	0.737	3.96	0.104	0.705
Tule Well** (TW)	10-08-78	1400	66.120	0.325	0.898	1.990	14.90	35.499	19.881
Tuseral* (TT)	10-08-78	1515	22.185	0.512	1.647	0.538	11.10	4.789	8.322
Papago Well**	10-09-78	1000	6.003	0.358	2.290	1.394	7.80	0.583	1.791

* Modified rock pools, ** Man-made tanks.

in the genera Oscillatoria and Anabaena. Secchi disc depths during this period declined to less than 10 cm, suggesting that light restriction from self-shading was important in the decline of chlorophyll a at depth.

Relatively low chlorophyll a concentrations in WT2 and WT181 (Figure 10) reflect the high degree of shading of these pools. Rock pool WT22 is less shaded than either WT2 or WT181 and would be expected to maintain higher chlorophyll a biomass. However, in this pool more than any other sampled, much of the algal standing crop was present as inadequately sampled filamentous green algae in the genera Oedogonium and Spirogyra. Predominance of these genera may have been attributable to a large boulder which deflected streamflow from this pool and greatly reduced scouring during all but major runoff events. The highly ephemeral and little shaded WT171 never contained water during summer visits when other pools had maximum chlorophyll a concentrations. Therefore, lower chlorophyll a values in this pool reflect seasonal variation rather than sustained shading during spring and summer.

DISCUSSION

Water quality criteria promulgated by government agencies generally lack standards or acceptable levels for many variables with respect to consumption by wildlife (Winter 1985, U.S. EPA 1986, Arizona Administrative Code 1987). Thus, it is difficult to state with certainty exactly what constitutes poor water quality for these animals. There are, however, certain water quality variables that are of almost universal concern for consumptive purposes, and they should be considered when evaluating rock pools as sources of water for wildlife (Figure 11).

Terrestrial wildlife using desert mountain rock pools as water sources encounter waters which differ greatly in quality, both temporally and spatially. With the exception of pools receiving groundwater input, it appears that the dissolved mineral content typically does not pose problems for wildlife consumption.

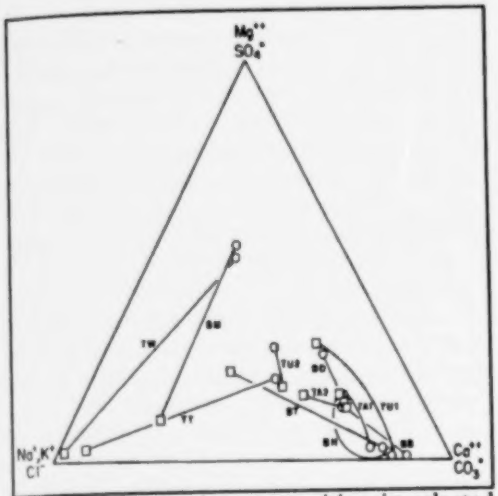

Figure 8. Major ion composition in selected rock pools and man-made tanks in southwestern Arizona. Squares=cations; circles=anions.

However, this generalization should be applied with reservation. Observations of conductivity levels in White Tanks rock pools reported in this paper were made during 1974-1977, years of nearly average rainfall. An August 1981 field trip to the White Tanks revealed conductivity levels in rock pools up to 18,200 uS cm^{-1}, more than 5X greater than the highest measurement taken during 1974-1977. Ironically, these conductivity levels occurred following a period of higher than average precipitation in the study area.

Where water drawn from wells is transported to rock pools or artificial tanks, the dissolved mineral content may be of special concern. Transported water supplies are subject to particularly high rates of evaporation, since this practice is largely limited to summer months in the southwest deserts, and considerable increases in dissolved mineral content can occur as water evaporates leaving behind the salt load. This will be especially true of groundwater initially high in dissolved salts. Where streamcourses have been modified to reduce flushing, this problem may be exacerbated, since dilute runoff waters will ordinarily act to remove some of these salts.

Evaporative concentration can also result in the solubility products of less soluble salts being exceeded (Cole 1968), thus changing the major ion composition of remaining water to combinations that have the capacity to produce ill effects. This process can be exaggerated in more concentrated rock pool waters where removal of carbon dioxide during intense photosynthesis causes calcium carbonate to precipitate (Carpelan 1967). Concentrated waters high in sodium sulfate or magnesium sulfate have long been noted for their emetic and laxative effects on humans (Thompson 1929). To what extent these problems may plague wildlife seems to have been little investigated.

Of the few desert mountain rock pools for which nutrient levels have been measured, concentrations appear to be more than adequate to support high levels of primary productivity and algal standing crops. The small size of these pools and the unpredictable nature of runoff events that supply nutrients, both in frequency and magnitude, potentially limits the period over

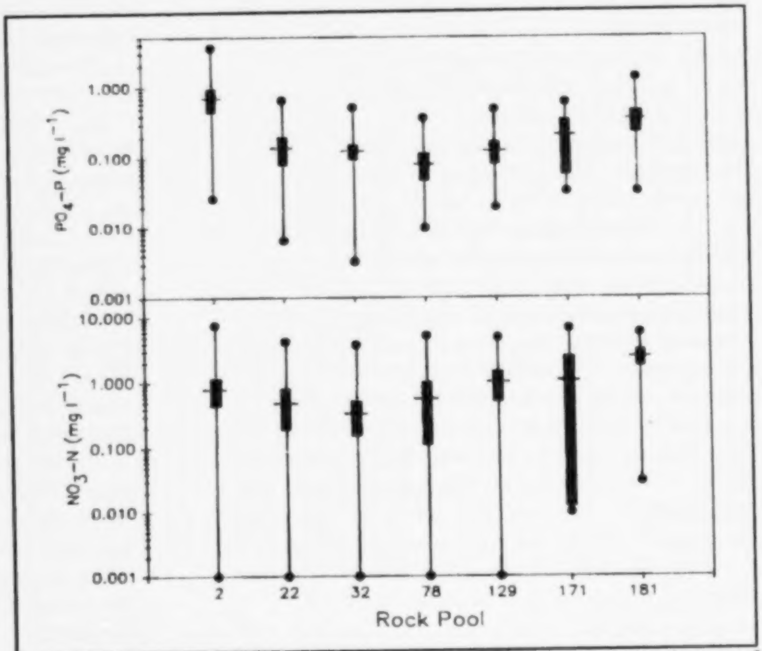

Figure 9. Mean, 95% confidence interval, minimum, and maximum of orthophosphate-phosphorus and nitrite-nitrate-nitrogen concentrations measured in White Tanks rock pools during the period October 1974-March 1977.

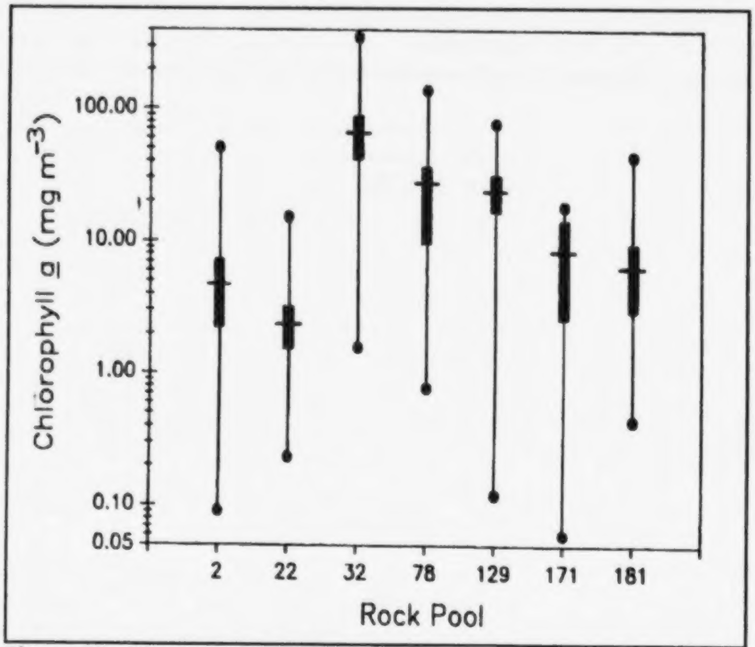

Figure 10. Mean, 95% confidence interval, minimum, and maximum of planktonic chlorophyll a concentrations measured in White Tanks rock ools during ther period October 1974 - March 1977.

which high rates of algal photosynthesis can be sustained. However, studies on rock pools in other settings, from Baltic seacoasts (Ganning 1969) to tropical Africa (Osborne and McLachlan 1985), suggest that external loading from animal deposits (feces and drowned bodies) and internal loading from sediments and heterotrophic organisms may be important nutrient contributors to sustained productivity.

Chlorophyll a levels and dissolved oxygen profiles in desert mountain rock pools are further indicative of highly eutrophic systems. The maximum chlorophyll a concentration in the deepest White Tank rock pool, over 350 mg m^{-3}, is apparently the highest value recorded for a natural water body in Arizona, and it exceeds even the maximum value for a reclaimed wastewater pond in Phoenix (Foster and Idso 1975). It should be emphasized, however, that the trophic state of rock pools in the same drainage varies according to season, exposure to sunlight, morphology (particularly depth), and duration of existence.

Markedly high concentrations of planktonic chlorophyll a in desert mountain rock pools provide subsequent high amounts of organic matter that must be oxidized in relatively small volumes of water if not flushed by spates. Additional organic loading from external sources arrives in runoff, as leaf drop from poolside trees, and from excrement and bodies of drowned animals including a range from terrestrial insects to big game. Early investigators recognized that steps should be taken to restrict the amount of organic matter in rock pools or other water supplies intended for use by humans because of the increased potential for the buildup of populations of pathogenic bacteria (Bryan 1925).

Microbiological investigations apparently have not been conducted on desert mountain rock pools, but the combination of seasonally warm water temperatures, aerobic and anaerobic zones, and high nutrient levels, including both autochthonously and allochthonously derived organic matter produce an excellent medium for the growth of many water-dwelling bacteria and viruses. Several important diseases of desert bighorns are caused by bacterial infections (Jessup 1985, Smith and Krausman 1988 and references therein), but there seems to be limited knowledge of the role that transmission via water supplies may play in the passage of the disease organisms.

Bacteria certainly play an important role in the determination of water chemistry, and thus water quality. An excellent example is the role that certain heterotrophic and anaerobic bacteria play in the reduction of sulfate to hydrogen sulfide concomitant with the oxidation of organic matter to carbon dioxide (Wetzel 1983). Although meromixis in desert mountain rock pools, as postulated by Cole (1963), seems restricted by flushing, sustained periods of anoxia have been measured in perennial pools. Particularly in deeper pools, the combination of sustained stratification, prolonged anoxia, and large amounts of organic matter provides an environment most suited for bacterially-mediated production of noxious or toxic ions or compounds. These conditions, coupled with decreases in sulfate concentrations at depth and the aroma of hydrogen sulfide in summer, suggest concerns for wildlife consuming these waters similar to those that have been expressed for fish in water bodies of the desert southwest (Clark and Greenbank 1936).

Hydrogen sulfide criteria for water consumption by livestock or wildlife have not been developed, because it is held that the unpleasant odor and taste would preclude use at hazardous concentrations (U.S. EPA 1986). This assumption may not hold, however, for desert wildlife lacking alternative supplies. While hydrogen sulfide and other toxic or noxious substances may seldom, if ever, be directly responsible for the death of desert bighorns, they can certainly be debilitating to animals already under physiological stress from lack of water, disease, parasitism, and other factors.

Summer phytoplankton communities in exposed desert mountain rock pools measured during this investigation were characterized by blooms of blue-green algae in the genera Anabaena and Oscillatoria. Several taxa of blue-green algae, including Anabaena flos-aquae, are known to produce exotoxins which can cause death in domestic animals and wildlife (Carmichael 1981). The response to these toxins varies among species and individuals depending upon dosage, amount of food material in the gut, and differences in sensitivity (Gorham and Carmichael 1980, Carmichael and Briggs 1978).

Desert mountain rock pools are habitats for numerous aquatic invertebrate and vertebrate species, some of which may serve as vectors for the transmission of desert bighorn disease organisms and parasites. For example, ceratopogonid gnats in the genus Culicoides are known to be vectors of the bluetongue virus (Jessup 1985). I am unaware of which Culicoides species serves as the infective agent for bluetongue, but it is well known that larvae of this genus occupy a wide variety of desert habitats from rotting cactus to small water-bodies (Wirth 1952), including desert mountain rock pools (D. Kubly personal observation). Jessup (1985) has noted, apparently based on the incidence of the disease, that desert bighorn at lower elevations having abundant manmade and natural water sources are frequently exposed to bluetongue. He has equated this relationship to increased contacts with domestic livestock, but perhaps there is another, equally formidable, relationship.

Two common practices in modifying rock pools to increase water quantity and duration of existence, the emplacement of dams and gabions, may serve the unintended purpose of degrading water quality. Dams increase the depth of water, and thereby the potential for prolonged thermal and chemical stratification in the water column. Increased duration of stratification provides a greater potential for the development of an anoxic zone in which organic matter decomposition leads to the production of noxious or toxic reduced substances. Furthermore, observed rock pool dams were elevated, sheer-faced structures which most certainly impede the flushing of particulate organic matter, especially that included in bottom sediments, from these basins during spates.

Upstream gabions serve to maintain rock pool volumes by reducing the input of coarse sediments and organic debris into the basin during spates, i.e., they act as filters. Some gabions are constructed at an angle to the stream course in order to divert a share of the stream flow and debris away from rock pools. This has the desired effect of reducing input of unwanted material, but it also acts to reduce flushing of particulate organic matter. Therefore, input of organic matter produced outside the pools may be reduced, but at the expense of increased organic matter produced within the pools.

CONCLUSION

Anthropogenic alterations of desert mountain rock pools, including removal of sediments and construction of dams, covers for in the analysis of costs and benefits brought about in the process of increasing water quantity.

Water quality factors deemed worthy of consideration in desert mountain rock pools include, but are not restricted to: (1) dissolved mineral content; (2) major ion composition; (3) pH; (3) organic matter concentration; (4) noxious or toxic reduced substances; (5) blue-increased shade, and upstream gabions have improved both the number and distribution of perennial water sources for desert wildlife. It appears, however, that in the quest to increase the quantity of water available for wildlife, there has been little attention given to the quality of water. Limnological investigation of both natural and altered rock pools and related catchments suggests that water quality should be considered green algae; (6) pathogenic bacteria and viruses, and; (7) vectors of parasites and disease-producing organisms. Analyses of water quality in desert mountain rock pools and related catchments should concentrate on summer conditions, since this is the time of year when water quality is most impacted by natural processes and when wildlife suffer the greatest physiological stress.

Dams and gabions may have mixed effects on rock pool water supplies consumed by wildlife. They have the capacity to increase the quantity of water, but diminish water quality. Engineering and construction of rock pool dams and gabions should be examined to determine if better designs are available that would accomplish desired effects for both water quantity and quality. Changes in design need not necessarily be complex; minor modifications might prove to be most beneficial.

ACKNOWLEDGEMENTS

I thank Gerald Cole for providing the spark of interest in desert mountain rock pools that led, at long last, to my putting down in writing the findings contained in this paper. The reviews of Jim Burton, Rob Clarkson, and Larry Riley were very helpful in improving the manuscript.

LIST OF FIGURES

Figure 1.	Map of Arizona showing climatic regions and location of mountain ranges from which rock pool samples were collected. AM = Aguila Mts., BB = Baker Butte (Peak), CP = Cabeza Prieta, SE = Sierra Estrella, SM = South Mountain (Salt River Mts.), TA = Tinajas Altas, TM = Tule Mts, WT = White Tank Mts.
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Figure 10.	Mean, 95% confidence interval, minimum, and maximum of planktonic chlorophyll a concentrations measured in White Tanks rock pools during the period October 1974-March 1977.

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Table 4. Chemical and biological water quality parameters of potential concern to wildlife consuming water supplies from desert mountain rock pools.

Chemical Constituents

Factor	Concern
High dissolved solids	Physiological distress, salt balance.
Major ion composition	Emetic and laxative effects from concentrated sodium sulfate, magnesium sulfate, and sodium chloride waters.
pH	Salt balance, effects on other chemical constituents.
High organic matter	Odor, taste, oxygen consumption, enhanced bacteria populations.
Reduced substances	Noxious and toxic, e.g. hydrogen sulfide and ammonia or ammonium hydroxide.

Biological Constituents

Factor	Concern
Blue-green algae	Taste, increased organic matter, direct toxicity (*Anabaena flos-aquae*, *Microcystis aeruginosa*, and *Aphanizomenon flos-aquae*), high pH during blooms.
Bacteria	Possible disease organisms, produce reduced substances during decomposition of organic matter.
Invertebrates	Possible vectors for parasites or disease-producing organisms.

CONTROL OF TAMARISK AT DESERT SPRINGS

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Abstract

Deciduous tamarisk or saltcedar, a non-native tree from Eurasia, has invaded remote desert springs by wind transport of its pollen-size seeds. Tamarisk can impact wildlife directly by drawing down surface water levels of desert springs or by forming physical barriers to animal access. In addition, the tree aggressively displaces native riparian vegetation utilized for food by insects, birds and mammals. Tamarisk eradication is practical at isolated springs because the small seeds lose viability over a single hot summer. Removal of the tree involves cutting or girdling the trunk near ground level and lightly spraying the cut bark surface with a systemic herbicide, Dow Chemical's Garlon 4. This herbicide has low toxicity to animal life, and it decomposes rapidly in the environment. Once a spring area is cleared of tamarisk, infrequent monitoring is necessary for removing any regrowth and new seedlings.

IMPACT ON WILDLIFE

Deciduous tamarisk is an exotic shrubby tree, native to Eurasia, that has invaded springs and riparian areas throughout desert areas of North America. Tamarisk can impact wildlife in at least three ways:

(1) Tamarisk transpires groundwater at high rates and grows more densely than native phreatophyte trees, so it can curtail the flow of surface water from desert seeps and springs that are essential for wildlife survival.

(2) Dense tamarisk growth can form physical barriers that prevent access of large mammals to desert water sources.

(3) Tamarisk displaces native trees and shrubs that are important food sources for wildlife, but its own tough, scaly leaf and pollen-size seed are not eaten by insects, birds or mammals.

SPRING FLOW RESTORED BY REMOVAL

At two desert springs in California, tamarisk removal has dramatically restored the flow of surface water:

> At Eagle Borax spring on the floor of Death Valley, rapid tamarisk growth during the 1960's displaced marsh vegetation and caused the spring to dry up completely. In 1972, when the vitality of adjacent mesquite trees had declined visibly, the National Park Service burned the area to restore water flow, then started permanent removal of tamarisk using chainsaws and herbicide. Following tamarisk removal over the next decade, shallow ponds spread over an acre, approximately, and the marsh vegetation and mesquite grove recovered rapidly.
>
> At Red Rock Canyon State Park, a tamarisk thicket measuring 50 ft by 25 ft was removed during 1987 next to a small spring in a dry wash. Before removal, the seep produced at most a few puddles of surface water and dried up completely during summers. Tamarisk removal increased water flow by many times. Perennial surface water now flows a half mile down the wash, and the zone of native riparian vegetation is expanding greatly.

TAMARISK IDENTIFICATION

The invasive species of tamarisk is deciduous and flower-bearing; it normally drops its leaves in winter, and produces numerous small pink flowers in spring or summer that cluster at the ends of stems (Figure 1). The scaly leaf resembles that of cedar, hence the common name "saltcedar."

The taxonomic name of invasive tamarisk is unsettled, but "Tamarix ramossisima", meaning "multi- branched", seems the most descriptive. Where the tree grows unconfined, it commonly has radiating multiple trunks that give it a spherical shape (Figure 2).

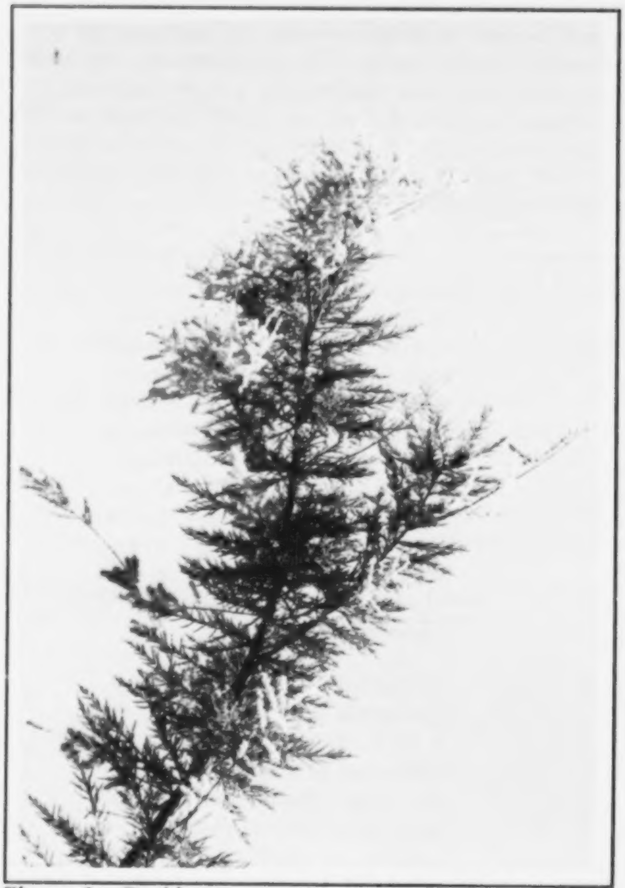

Figure 1. Deciduous tamarisk in bloom, showing small white-to-pink flowers and scaly, cedar-like leaf.

A second variety of tamarisk in desert areas is "Tamarix aphylla", commonly known as "athel". It is evergreen, with inconspicuous flowers, large solitary trunks, and leaves resembling pine needles. It is not nearly as invasive as deciduous tamarisk, for the seed lacks viability and the tree propagates by the transport and burial of broken limbs during floods. Consequently, it is absent at isolated springs unless planted.

FEASIBILITY OF ERADICATION AT SPRINGS

Around desert springs that are never flooded, tamarisk removal must be complete to be effective; but once accomplished, the rehabilitation should be permanent, with only minor surveillance needed to remove seedlings derived from distant seed sources.

A single large tamarisk tree produces a half million pollen-size seeds per year, which can disperse widely by wind or water. To permit this seed abundance and long-distance transport, the seed size must be small. But as a result of its small size--and to compensate for its prolificacy--tamarisk seed loses most of its ability to germinate within several months at summer temperatures (Horton et al, 1960).

The short timespan of seed viability makes tamarisk eradication feasible at desert springs that are remote from other seed sources. Once all mature trees and seedlings have been removed manually, the bank of viable seeds remaining on the soil surface should disappear after a year.

In contrast, in desert canyons subject to flooding, work should target primarily the larger trees at higher elevations which are likely to survive future floods and reseed the canyon floor; younger trees and saplings, particularly at the lowest elevations, can be ignored as they eventually will be washed away.

HERBICIDE RECOMMENDATION

Deciduous tamarisk is difficult or impossible to kill by fire, drought, freezing, hypersalinity, prolonged submersion, repeated cutting at ground level, and herbicide applications to the foliage. In most cases, effective removal requires cutting the bark near ground level and applying a systemic herbicide to the cambium layer.

During the past 15 years, the herbicides used for cut-stump treatment of tamarisk have been, in chronological order: Silvex, Tordon, Garlon 3A, and Garlon 4. Silvex was highly effective, but prohibited by the EPA in the 1970's.

Tordon is "restricted" to use by licensed applicators because it is persistent in the environment; Dow Chemical has discontinued its sale in California, but will not necessarily do so in other states. Garlon 3A is not legally 7restricted, but it has the disadvantages of being expensive and hazardous to the eyes.

Dow Chemical's Garlon 4 is the current favorite, combining the best features of its predecessors. Like Silvex, it is more effective at killing tamarisk than either Tordon or Garlon 3A. Like Tordon, it is relatively cheap, after dilution with 2 parts water. And like Garlon 3A, Garlon 4 is environmentally safe, yet will not cause injury to human applicators.

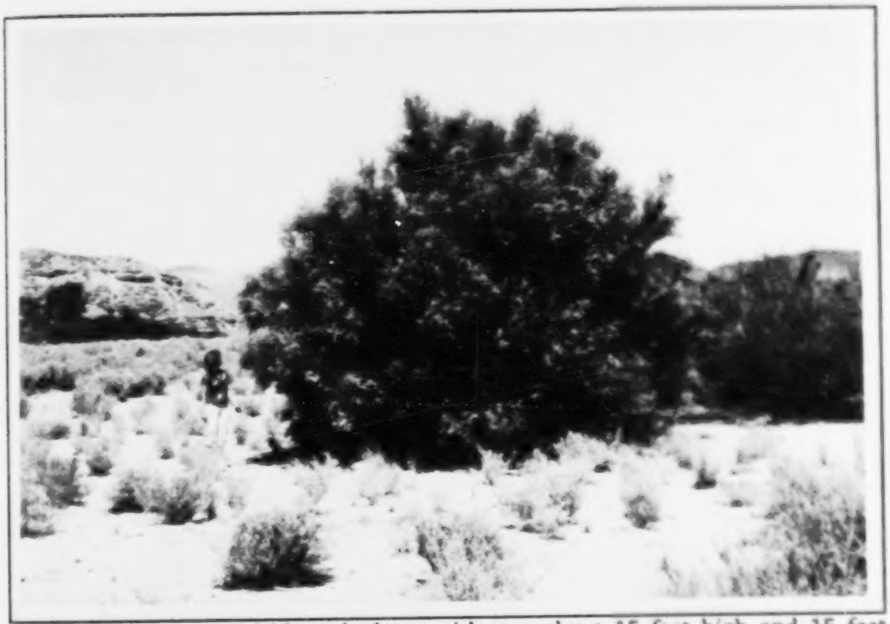
Figure 2. Mature, multi-branched tamarisk tree about 15 feet high and 15 feet wide. Note figure on left for scale.

Garlon is not a restricted herbicide because it decomposes rapidly after application, in a day or less in sunlit water, and something like two weeks to two months in soil. Therefore it can be used by applicators without state certification and without a permit from the county agricultural agent.

Garlon 4 contains 4 lbs/gallon of the active agent, triclopyr, as a the oil-soluble ester. It also contains petroleum distillates as a carrier, with surfactant to allow mixing with water. According to Dow Chemical's technical data sheet, Garlon 4 has low oral toxicity, and is non-irritating to skin and eyes, as judged from tests on rabbits.

A temporary problem with Garlon 4 is that the use directions currently do not allow cut-stump applications outside of California and the Pacific Northwest. In other states, applicators wishing to use Garlon 4 for cut-stump treatments should obtain Special Local Needs (SLN) registration from their respective state agricultural offices.

GARLON 4 PREPARATION

Wilbur-Ellis Company is the wholesale distributor of Garlon 4 in the western states. The minimum quantity of 5 gallons costs about $400. This amount should be extended to 15 to 20 gallons by dilution with water.

The optimum dilution of Garlon 4 for tamarisk treatments is being determined by experimentation. What we know currently is that Garlon 4 mixed with 2 parts water gives excellent results. But because most applicators overspray, a more dilute mixture with 3 parts water ought to deliver an adequate amount of herbicide at less cost.

Higher dilution ratios with perhaps 5 parts water are expected to result in lower mortality of the treated stumps; but lower herbicide efficacy might be cost-effective if an area can be accessed easily for follow-up treatments.

When mixed with water, Garlon 4 takes on an opaque white color which disappears quickly after it is sprayed on a stump. Addition to the mixture of some blue Rit dye will greatly assist recognition of sprayed and unsprayed stumps. One 8 oz. bottle of liquid dye will turn about 6 gallons of diluted herbicide to a pale blue color which persists after drying.

HERBICIDE CONSUMPTION

A single gallon of diluted Garlon 4 herbicide should be sufficient to treat hundreds of trees or thousands of seedlings. Only a light spray is required on the cambium layer next to the bark; the interior portion of thick trunks, cut off at ground level, can be left dry.

As a general guideline, a group of 10 workers can be expected to use about one gallon per day, if they work efficiently with appropriate tools and do not apply herbicide too heavily.

RECOMMENDED EQUIPMENT

The essential tools for cutting tamarisk are lopping shears, hand axes, and chain saws. For lopping shears, "Sears Best" is recommended, described as follows by the Sears 1988 Lawn and Garden Sale Catalog:

> Lopping shears with compound cutting action cuts branches up to 1.5 inches thick. Teflon-coated steel blades with adjustable anvil and hardwood handles. 28.25 inches long overall. Wt. 3 lbs. 8 oz. 71 M 86128C .... Thru 8/1/88 $17.99; After $24.99

The quality and mechanical leverage of these compound-action shears give notably improved productivity compared to conventional scissor-type shears, and are well worth the extra expense, whether on sale or not.

For larger trees, a chain saw will be optional or required, depending on the accessibility of the main limbs. Thick, solitary trunks are more easily treated by girdling with a hand ax, rather than by felling the tree and spraying the stump, because with girdling, the tall heavy limbs do not require removal. More commonly, however, deciduous tamarisk is multi-trunked, and partial or complete cutting is needed to gain access to the entire bark surface at ground level.

In most cases, hand-held spray bottles with a trigger lever can be used for applying the herbicide. These are obtainable at garden supply stores.

An applicator following several chainsaws in a dense stand of tamarisk will find it convenient to use a larger dispenser, with a hand pump for pressurization and a short hose to the nozzle.

DISPOSAL OF CUTTINGS

Tamarisk cuttings can be voluminous. To permit access to stumps after cutting and avoid smothering the native shrubs and grasses, cuttings should be stacked nearby on dry bare ground or dead vegetation. Other than for aesthetic considerations, there is no reason to remove cuttings any significant distance from the work area. If not destroyed by flooding or fire, the cuttings will eventually decay in place.

Tamarisk seeds remaining on cuttings are not a cause for concern, because the seeds lose viability over a single hot summer.

SEASON OF YEAR

The instructions for Garlon 4 indicate that applications can be made at any season. Unlike Tordon, Garlon 4 seems to be acceptably effective during spring months when sap flow is strongly upward from the root system.

Because Tordon is more effective in the autumn and winter, when tamarisk is going dormant, we might expect Garlon 4 to be effective then at higher dilution ratios, but this supposition remains to be proven.

The late spring months--from April to June--are usually uncomfortably warm in the desert, but this period is the only practical time to search for tamarisk seedlings mixed with other vegetation, because only then can small plants be easily distinguished at a distance by their pink flowers.

HERBICIDE APPLICATION METHOD

The bark and cambium layer should be cut as close to the ground as feasible. As a general rule for applications of Garlon 4, the spacing between cut and ground level should be

6 inches or less. Higher cuts of 6-12 inches above ground are reportedly effective for applications of Garlon 4 during autumn months (Howard et al., 1983).

The bark wound can be made by either girdling with an ax or cutting the limb completely with lopping shears or chain saw. For larger trunks, girdling is the most effective treatment, because the shallow downward cuts tend to trap and pond the herbicide, allowing prolonged seepage into the vascular system.

Often, chain saw cuts must be made higher than a few inches from the ground to prevent the saw blade from striking rocks and soil. In such cases, the tamarisk stump should be girdled with an ax after cutting, before the herbicide is applied.

The herbicide should be applied within minutes of cutting. Waiting an hour or more before applying herbicide allows the tree time to start closing off the wound, so will lower the mortality rate drastically.

The entire circumference of a tree must be cut and treated, because herbicide adsorbed by the vascular system does not appear to move circumferentially in the root crown.

POST-APPLICATION MONITORING

Under favorable conditions the mortality rate of tamarisk after Garlon 4 treatment should exceed 95%. Less successful applications are usually attributable to not cutting or spraying the bark circumference completely or low enough to ground level.

Some amount of regrowth is inevitable. A follow-up visit to treat resprouting stumps is always necessary several months to a year after an (initial treatment. In some cases during the spring months, a treated stump will produce stems several inches tall before dying. For this reason, follow-up inspections should occur after 3-4 months have passed, so that there is no uncertainty over which stumps are dead and which are alive.

Tamarisk trees on floodplains can be more difficult to kill, requiring several treatments. The root systems are more extensively developed near the ground surface, due to repeated scouring and removal of limbs by floods, and can send up shoots where none existed at the time of initial treatment (Figure 3).

When surveying resprout densities, the applicator should remember that without herbicide, each cut stump would send up perhaps 10 to 30 shoots. If a treated stumps produces only one or several resprouts, then the herbicide has performed quite well by killing most of the root system. Cutting and spraying resprouts from a small percentage of stumps is easy work, compared to the initial treatment. If financial resources exceed labor resources, resprouting foliage can be sprayed with diluted Garlon herbicide without cutting.

Although proper applicationtechnique

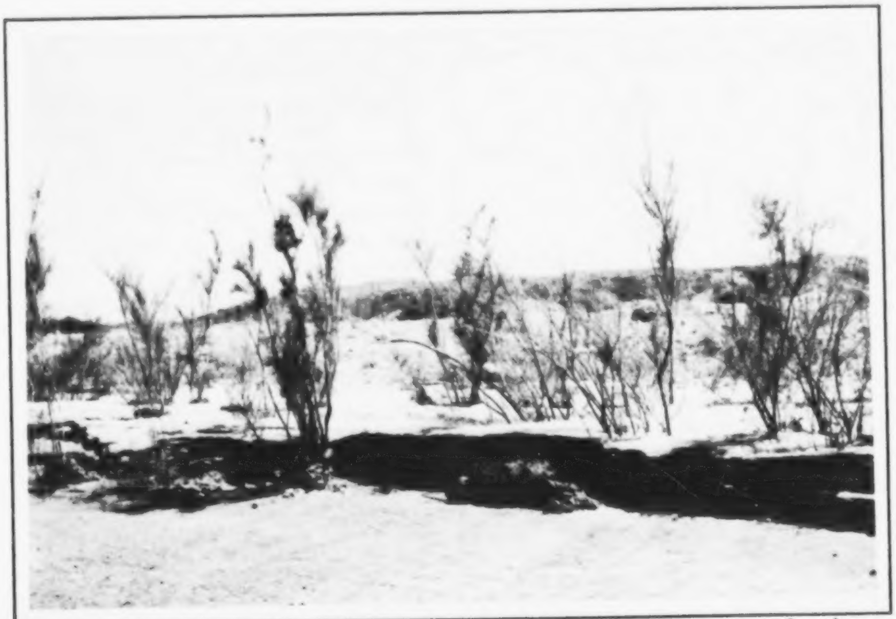

Figure 3. Young tamarisk seedlings in a flood channel - precursors of a dense, impenetrable thicket in ten to twenty years.

is important, it is necessary to find a balance between working with thoroughness and working with speed. When confronting shallow lateral roots or partly exposed root systems, for example, it is more efficient to work quickly on the first pass; then, after seeing what survives, one spends more time on follow-up visits at digging out and treating the more inaccessible roots.

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EFFECTS OF HUNTING ON WATER-USE BY DEER
PRELIMINARY REPORT

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Abstract

Mule deer (Odocoileus hemionus spp.) were observed while using two guzzlers, tree sumps, and two troughs in July through October 1987. Two hundred one deer visits occurred during 99 hours of observation. Watering occurred morning and evening hours, peaking between 20:00 and 20:30. Total drinking bout duration averaged 3.3 minutes for bucks, 2.3 minutes for does, and 2.0 minutes for fawns. Drinking duration averaged 2.2 minutes for bucks, 1.5 minutes for does, and 1.2 minutes for fawns. Bucks and does spent 33% of their drinking bout activity alert or interacting with other deer, and fawns spent 40%. The number of interruptions during a drinking bout averaged 3.9 for bucks, 2.7 for does, and 2.9 for fawns. Mean values for drinking bout duration, drinking duration, number of deer observed at guzzlers, sumps, and troughs were compared during non-hunting and hunting seasons and no significant differences were found.

INTRODUCTION

The study was conducted in the McCloud Ranger district of the Shasta Trinity National Forest in Northern California (Figure 1). This 864 square kilometer area ranges in elevation from 3,800 to 7,300 feet. The McCloud Ranger District is 82% forestland (Fox et al. 1983). The remaining 18% is composed of brush, lava, grass, and water. Water constitutes less than 1 percent of the district.

Columbian black-tailed deer (Odocoileus hemionus columbianus) and Rocky Mountain deer (O. h. hemionus), as well as hybrids of the two, inhabit the McCloud Ranger District of the Shasta-Trinity National Forest where this study occurred. The deer in the northeast portion of this district are dependent on sources of free-standing water (Ashcraft 1960). A water development survey conducted in this district by the California Department of Fish and Game in 1955-56 revealed restricted range use by deer and overuse of the range around existing water sources. Water development projects were proposed and installed as a result of that survey.

Water development project for wildlife have been used by state and federal agencies to mitigate impacts to habitat and to improve animal distribution and habitat use (Campbell and Remington 1979; Werner 1985; and McCarty 1986). Water developments used for these purposes include troughs filled via pipelines from large cisterns of springs, self-filling rainfall catchments (guzzlers), and bulldozed springs (sumps).

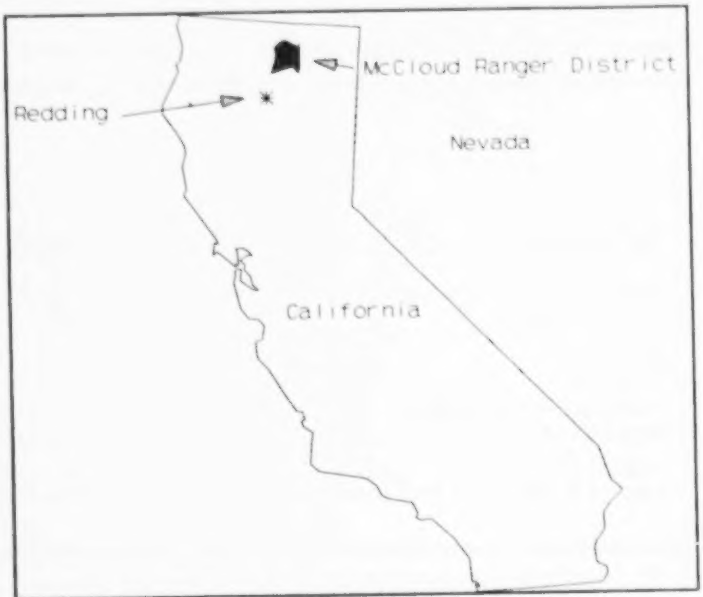

Figure 1. The McCloud Ranger District.

Desert mule deer (O. h. crooki) dependent on free standing water were found to move outside their known home range to water when denied access to sources normally frequented (Hervert and Krausman 1986). Bighorns (Ovis canadensis mexicana, and O. c. nelsoni) were found to modify their water use patterns to avoid human disturbances (Campbell and Remington 1981; Hamilton et al. 1982).

Deer hunting activity especially archery hunting, on the McCloud Ranger district is concentrated around the water sources where hunters frequently wait in ambush in a treestand overlooking a water source. The California Department of Fish and Game and the United States Forest Service are concerned about the possible effects of this type of hunting activity.

In order for water developments to serve their designed purpose, an assessment of which types of water sources and what disturbances are most likely to influence water use patterns is required. This study was initiated to provide information on how the type of water source and hunting affects deer water-use patterns on the McCloud Ranger District.

METHODS

Water-use patterns of deer were determined by observing deer watering at seven water sources, 2 guzzlers, 3 sumps, and 2 troughs (Table 1). Each observation period lasted three hours and all times of the day and night were sampled. Nocturnal observations were aided by illuminating the area surrounding the water source with a 12-volt red light. Observations were conducted from "blinds" greater than 30 meters from the water source. "Blinds" consisted of a portable treestand, ground blinds, and an automobile.

Data recorded, were: date of observation, time deer entered area, duration of time spent in the vicinity of the water source, duration of drinking bout (time elapsed between the first and last drink), number of interruptions within a bout, duration of each interruption, drinking duration, group composition, and direction from which deer approached and exited the area. Results were analyzed using the analysis of variance test (Zar 1984). Statistical significance was designated at $P < .05$.

RESULTS

201 deer visits occurred during 99 hours of observation. The composition of deer observed at the water sources is displayed in Figure 2. Watering occurred in morning and evening hours with watering activity peaking between 20:00 and 20:30 (Figure 3). No watering by deer was observed between 03:00 and 05:00 or between 11:00 and 14:00.

Table 1. Water sources monitored to observe mule deer water-use patterns.

	Type of Development		
Water Source	Guzzler	Sump	Trough
West of Red Hill	X		
South of 42N03	X		
Red Hill			X
Lava Crack			X
Hambone Pump Station		X	
White Deer Lake		X	
Mud Well		X	

Mud Well was monitored until it went dry then observations were made at Hambone Pump Station.

The mean drinking duration ranged from 1.2 minutes for fawns to 2.2 minutes for bucks (Table 2) and the mean duration for bucks was significantly greater than that for does (q=4.2, q 0.05, 106, 3=3.399) and fawns (q=5.29).

Table 2. Mean drinking duration (min) for mule deer.

	Drinking Duration		
Group	N	x	SD
Bucks	15	2.2	0.97
Does	67	1.5	0.78
Fawns	27	1.2	0.72

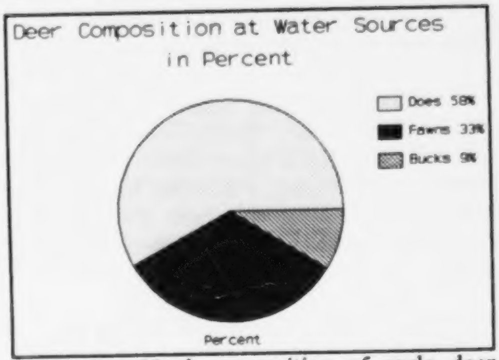

Figure 2. Herd composition of mule deer observed at water sources.

The duration of time deer spent in the vicinity of water developments ranged from a mean of 21.2 minutes for fawns to 8.7 minutes for does (Table 3). Duration for fawns was significantly greater (q=3.96, q 0.05, 180, 3=3=3.356) than that for does.

Total drinking bout duration averaged 3.3 minutes for bucks, 2.3 minutes for does, and 2.0 minutes for fawns. Duration for bucks was

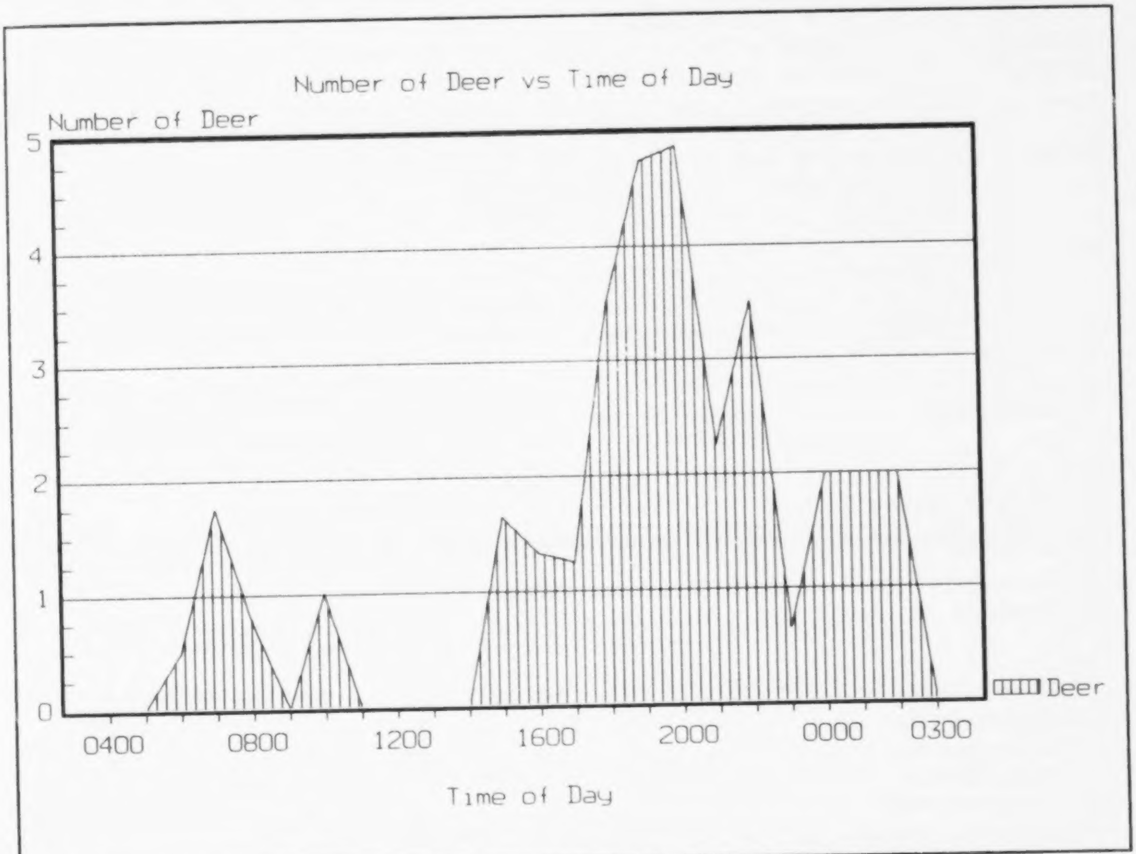

Figure 3. Watering schedule for mule deer on the McCloud Ranger District, California

significantly greater than that for does ($q=3.44$, q 0.05, 104, $3=3.399$) and fawns ($q=3.76$).

Bucks and does spend 33% of their drinking bout actively alert or interacting with other deer, and fawns spent 40%. The number of interruptions during a drinking bout average 3.9 for bucks, 2.7 for does, and 2.9 for fawns. These were not significantly different ($F=1.3$, $p>0.25$.

The mean values for number of interruptions per drinking bout, duration of interruptions, drinking duration, and drinking bout duration for deer observed at guzzlers, sumps, and troughs were compared. No significant differences were found among any parameters at the three types of water sources (Table 4). The above parameters were also compared during non-hunting and hunting seasons and again no significant differences were found (Table 5).

DISCUSSION

The summer deer herd composition observed at water developments in this study was similar to yearly fall herd composition estimates (California Fish and Game 1988). Consequently, in areas where deer are dependent on free-standing water, it may be possible to estimate pre-hunting season herd composition at water sources. If so the number of fawns per hundred does visiting water developments may be compared with fall estimates to estimate fawn mortality. Hervert and Krausman (1986) reported desert mule deer does could be censused based on frequency of visits to water developments.

This also may prove possible in the McCloud Flats study area. The diel patterns of watering activity observed (Figure 2) corresponded to periods when deer were most active. During midday periods deer were often observed bedded in shaded areas. At this time no explanation is available for the lack of activity between 03:00 and 05:00.

Table 3. Mean drinking duration (min) for mule deer.

	Drinking Duration of Water Developments		
Group	N	x	SD
Bucks	17	13.9	18.2
Does	105	8.7	9.1
Fawns	61	21.2	45.3

Theoretically, bucks have lower water requirements per unit of body weight than do does (Richmond et al. 1962). Fawns would be expected to have the highest water requirements. However, on average bucks drank significantly longer than does and fawns. It is possible that drinking duration is not a one to one correlation to water consumed, but it is not probable that bucks consumed less water per second while drinking than does. It is, however, possible that fawns consumed less water per second than does. Hervert and Krausman (1986) reported that under similar conditions desert mule deer bucks watered less frequently than does. Bucks may then be required to water longer to replace a greater percentage of their body weight. It is not

Table 4. Mean values for the number of gaps per drinking bout, gap duration, drinking duration and drinking bout duration for deer.

	Guzzler	Sumps	Troughs	
Parameters	x	x	x	P
Gaps per drinking bout	3.8	2.7	2.7	P>0.10
Gap duration (sec)	55	41	51	P>0.25
Drinking duration (min) for bucks	2.2	1.6	2.6	P>0.25
Drinking duration (min) for does & fawns	1.5	1.4	1.4	P>0.25
Drinking bout duration (min) for bucks	3.2	2.3	3.8	P>0.10
Drinking bout duration (min) for does & fawns	2.3	2.1	2.1	P>0.25

known if this occurred with bucks within this study area.

Behavior of bucks and does at water developments did not differ significantly. Both were similar in their duration in the vicinity of the development, mean number and duration of interruptions during a drinking bout, and percent of time during a drinking bout actively alert or interacting with other deer. The number of interruptions per drinking bout for fawns was not different than that for bucks and does. Fawns were observed spending a greater percent of their drinking bout actively alert and interacting with other deer. Playful and inquisitive behavior in fawns may explain this difference from adults.

Does and fawns commonly entered and left the vicinity of a development together. At Mud Well on August 25, 1987, a doe with four fawns left the vicinity of the development while the fawns remained. The fawns remained in the vicinity of the development for 3.15 hours. This duration greatly skewed the mean value for fawns, resulting in fawns staying in the vicinity significantly longer than does.

If the type of water source and hunting activity had an adverse affect on watering behavior, deer were predicted to display one or more of the following: (1) alteration of time the type of water source and hunting activity had an adverse affect on watering spent in the vicinity of the development, (2) less frequent visitation and increased drinking duration, (3) more frequent visitation but drink less, (4) increase in the duration of interruptions. No changes in behavior occurred.

The small size of troughs resulted in competition for watering space among deer visiting the development. Steep sides on sumps and low water levels in guzzlers required deer to enter into a situation where a predator could not be detected by sight until it was in close proximity. The constraints associated with these water developments did not result in significantly different behavior. It may be that the variables at developments such as wind velocity, and deer group size and composition and behaviors exhibited while watering obscure actual differences.

During hunting season, particularly archery season, hunting pressure is concentrated near water sources. Hunting pressure had no significant effect on any measures to estimate water-use patterns. Intensity of disturbance to deer watering during archery season was low. Archery tackle is often meticulously scrutinized by archers to prevent all extraneous noise. It is possible with this type of equipment to shoot at deer, miss, and not frighten the deer. A method frequently used at water developments uses treestands to get the hunter and his scent above the deer. Archers using quiet equipment, treestands, camouflage face paint and clothing, and scent mask human odor may not have been disruptive to deer, particularly if they sat quietly while over 91% (does, fawns and illegal bucks) watered.

During gun season human disturbance consists primarily of vehicle traffic. Intensity of the disturbance at water developments is minimal since the disturbance is predictable and harassment is minimized by a brief encounter. Deer appear to have adapted to the disturbance by waiting in or moving into the brush while vehicles pass. Vehicular disturbance at developments which were screened by dense brush at times caused no observable response by drinking deer.

Table 5. Results of ANOVA tests on water-use patterns for mule deer among the groups prior to archery season, during archery season, between archery and gun season, and during gun season.

Parameter	Probability
Gaps per drinking bout	P>0.25
Mean gap duration	P>0.25
Mean drinking duration for bucks	P>0.25
Mean drinking duration for does and fawns	P>0.25
Mean drinking bout for bucks	P>0.25
Mean drinking bout for does and fawns	P>0.25

The behavior of deer at water developments is influenced by many factors. It is possible two different factors could result inthe same observable behavior. For instance, a hunter or deer approaching a drinking deer many interrupt the drinking duration of the deer. The response, an interruption in the drinking bout is the same. The stimuli that resulted in the response is not addressed. This may be important since to stimuli may result in the same response but have different associated stress.

RECOMMENDATIONS

The effects of temperature, moon phase, distance of water developments from roads, and distance from water developments to their nearest neighbors in addition to the effects of type f development and hunting on water-use patterns should be investigated.

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ARTIFICIAL WATER DEVELOPMENT DESIGN, MATERIALS, AND PROBLEMS ENCOUNTERED IN THE BLM, CARSON CITY DISTRICT, NEVADA

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Abstract

Problems encountered due to equipment access, environmental conditions, and land management classification as well as the animal species will influence the type of materials, canopy (apron) size and needed water holding capacity of an artificial water development (guzzler).

INTRODUCTION

In many areas water is needed to improve wildlife habitat and quite often is the easiest habitat component to provide. At the onset of the water development proposal the wildlife biologist will know which animal species, or group of species he will be managing for, which will determine the approximate size of the development. There are many guzzler designs and materials available to the wildlife biologist. Design and type of material will be decided on depending whether the materials have to be flown or trucked into the site. How much rock is present may decide whether the site is suitable or not. Precipitation and wind conditions in the area will dictate the size and type of canopy material used. The land management classification such as a Wilderness Study Area may dictate the size of the development, color and the amount of surface disturbance allowed. The purpose of this paper is to describe what materials and designs have been used to solve the previously described problems in the construction of artificial water developments by the Bureau of Land Management, Nevada Department of Wildlife, and the California Department of Fish and Game in the Carson City District, Nevada.

DISCUSSION

The first criteria for site selection is placement of the water in the best habitat for the species you are managing for and whether the development will be multiple use or used only by wildlife. If the development is going to be multiple use i.e. allow livestock use in addition to the key wildlife species the development will probably have to be designed to hold 10,000 gallons or more. The first attempts (1960's) at large artificial water catchments (or reapers) in the Carson City District were failures. These developments used 10,000 gallon butyl rubber bags for water storage and heavy visqueen with fiber interwoven for the (water collection) apron. Tires were placed on the visqueen to prevent wind damage. Failure occurred due to ultra violet and wind damage to the visqueen and the butyl rubber. Recent (1980's) attempts at reapers in the Carson City District have used an 8,000 to 10,000 gallon steel tank and new plastic or polyester liners (see Attachment #1 for product names) which are resistant to ultra violet damage (approx. 20 years) and heavy enough (.036 in.) to prevent wind damage. This type of development is particularly useful in antelope ranges because heavy equipment can be used for burying the steel tank and clearing the site for the placement of the apron on the ground (at least 10,000 sq. ft.). Weighing the apron down (with tires) is still imperative. Steel tanks cost $4,000 to $5,000 and the apron liner is approximately $5,000 ($.50 / sq. ft.).

An apron laid on the ground with the low end running directly into a buried fiberglass tank was an early guzzler design by the California Department of Fish and Game. The soil covered fiberglass tank (750 gallons) is designed to allow upland game to walk directly down to the water inside the tank. This design is inexpensive ($800), simple, requires few materials and requires less digging. One disadvantage to this design is that any debris blown onto the apron tends to wash into the tank.

A basic design used in the Carson City District (See Table 1.) for upland game guzzlers (materials-$1,250) is a sixteen foot square corrugated steel roof (12 panels of 32 in. by 96 in. of 24 ga. steel) supported by 3 steel cross member beams (18 ft.-14 ga. "c" beams) over a 750 to 900 gallon buried fiberglass tank (Figure 1). The Nevada Department of Wildlife has used 12 - 16 foot interlocking 22 gauge steel sheets (See Table 2.) with no maintenance problems. Care has to be taken when the super structure of the canopy is assembled to be sure it is square. The BLM and Nevada Department of Wildlife have used two types of fiberglass tanks, a round cylindrical one piece tank and a square one piece tank with full removable lid and walk down ramp. We recommend the one piece 900 gallon tank (112 in. x 52 in. x 30 in. -bottom dimensions) with the removable lid for maintenance. A gutter (galvanized or plastic) at the low end of the roof collects the water and is piped into the tank. The new plastic gutter materials are much easier to construct, but may be prone to fire damage.

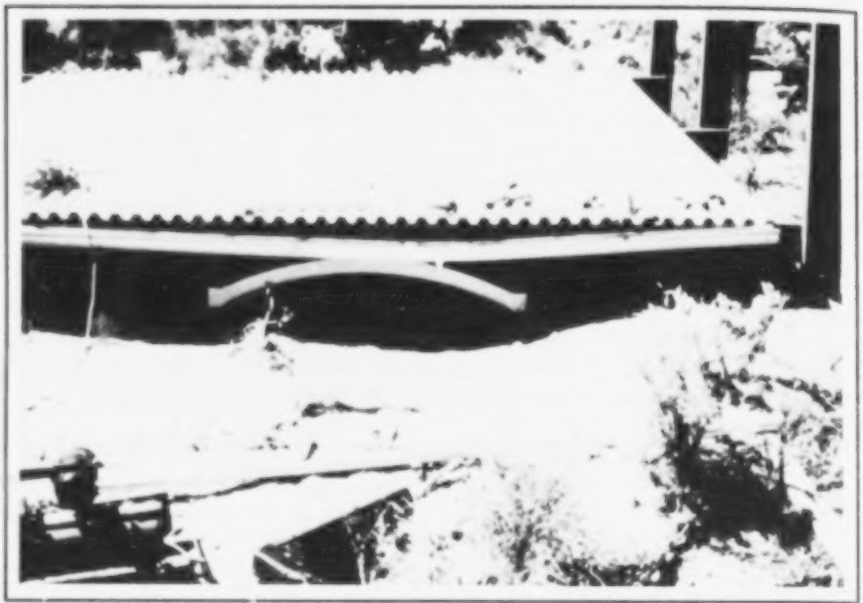

Figure 1. Partially completed upland game guzzler with 16 ft. x 16 ft. steel canopy over a 900 gallon fiberglass walk-in storage tank.

Table 1. Numbers and Types of Guzzlers in the Carson City District

Agency	# of Guzz.	Storage/ Gallons	Key Spp.	Self Level/ Float Valve	Canopy Type	Modular/ Parabolic
BLM	2	2200/2500	Bighorn Antelope Deer	Self Level (add on)	Steel	X
BLM	5	2800/3500	Bighorn Deer Antelope	Pressure/ Float Valve	Steel	
BLM	3	2700/2900	Deer	Self Level	Steel	
BLM	1	900	Chukar	Self Level		X
BLM	1	200	[1]/Chukar	Self Level		X
BLM	87	750/900	Chukar	Self Level	Steel	
NDOW	16	750/900	Chukar	Self Level	Steel	
NDOW	18	325	Chukar	Self Level	Steel	
CDFG	2	750	Chukar	Self Level	Butyl Rubber	
Total	135					

[1]/Pipe ephemeral spring to

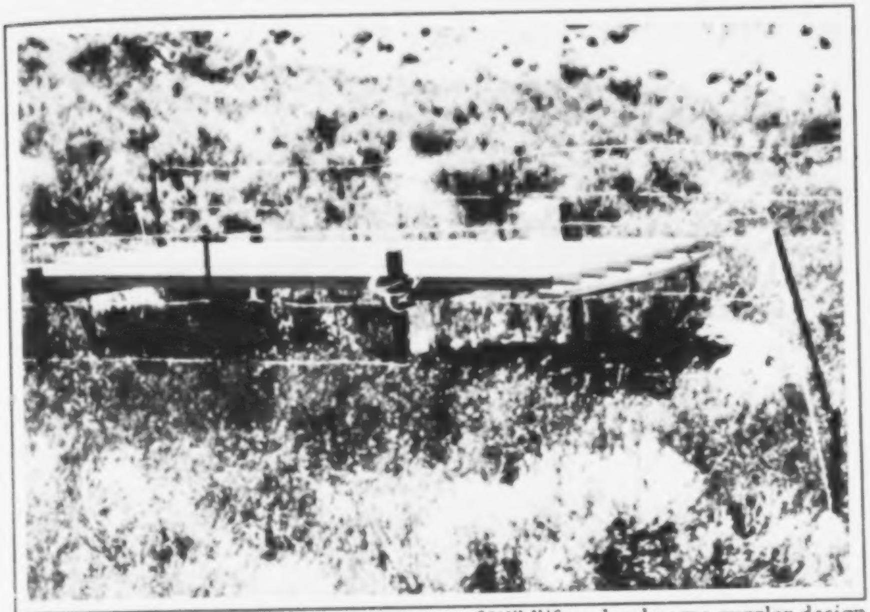

Figure 2. New (1987) Nevada Department of Wildlife upland game guzzler design with 8 ft x 12 ft. steel canopy over a 325 gallon fiberglass walk-in storage tank.

However, I have observed 4 units after fires with no damage to the plastic gutter. This 256 square foot canopy is adequate to fill the 900 gallon tank in a 6 inch rainfall zone. This design offers a shaded area for wildlife to loaf under while also keeping the stored water cooled, reducing water loss from evaporation. The tank opening (at least 8 inches high) should be pointed away from the prevailing winds and sun if possible to prevent evaporation and help moderate debris collecting in the tank. I have observed this design through two droughts in Nevada and have never seen a 750 or 900 gallon tank go dry. The Nevada Department of Wildlife developed an early (1950's) design similar to this with a wood frame. The wood frame will not stand up to wild fires and the burning wood often caused the fiberglass tank to burn down to the water level in the tank. An attempt was also made to use fiberglass sheets for the canopy, but the fiberglass was easily damaged by wind, fire and vandals.

The Nevada Department of Wildlife has developed another smaller upland game guzzler design (Figure 2.) in the same configuration as described above with a 8 by 12 foot steel interlocking canopy (6 panels, 16 in. by 144 in.) and 325 gallon (one piece with removable lid) fiberglass water tank. This 96 square foot canopy is adequate to fill the 325 gallon tank (52 in. x 52 in. x 24 in. -bottom dimensions) in a 6 inch rainfall zone. However, this unit was designed for a 8 in. to 10 in. rainfall zone with 1 1/2 in. to 2 in. occurring during the summer months when the water is critical for the chukar. If the precipitation is available and occurs at the right time of the year this design is less expensive (materials $650), and much easier to transport and construct than the larger designs. Further observation will be required to see if this design will maintain water during drought years in the lower rainfall zones which occur in the Carson City District.

This canopy design has also been expanded for mule deer, antelope and bighorn sheep by using two sixteen by sixteen foot square foot canopies combined on a steel frame (6 "c" beam cross members) large enough to fill 3,000 gallons of water storage in a 9 inch rainfall zone. We have used a broad variety of water storage tanks. One unit, on a site accessible to trucks, used a 3,500 gallon steel tank. Currently, our most successful design (Figure 3.) is two 1350 gallon seamless fiberglass (septic) tanks, leveled, and plumbed together with 30 to 40 foot pipeline to a walk-in, 100 gallon, drinker (materials - $3,400). The drinker in this design requires a float valve or a in-line pressure valve (we have used one on a guzzler) to regulate the water height in the trough. The in-line pressure valves only have a 1/8 inch port for the water to pass through and are very slow to refill the trough. In spring developments we have had clogging in the pressure valves due silt and calcification. We have been covering the float valve with a steel cover to prevent vandalism or damage from animals. All of the materials including the tanks (450 lbs. ea.) are light enough to be flown by helicopter to a site. Each tank (12 ft.long x 6 ft.wide x 5 ft.high) is buried 4 to 5 feet deep with the 16 ft. by 32 ft. canopy

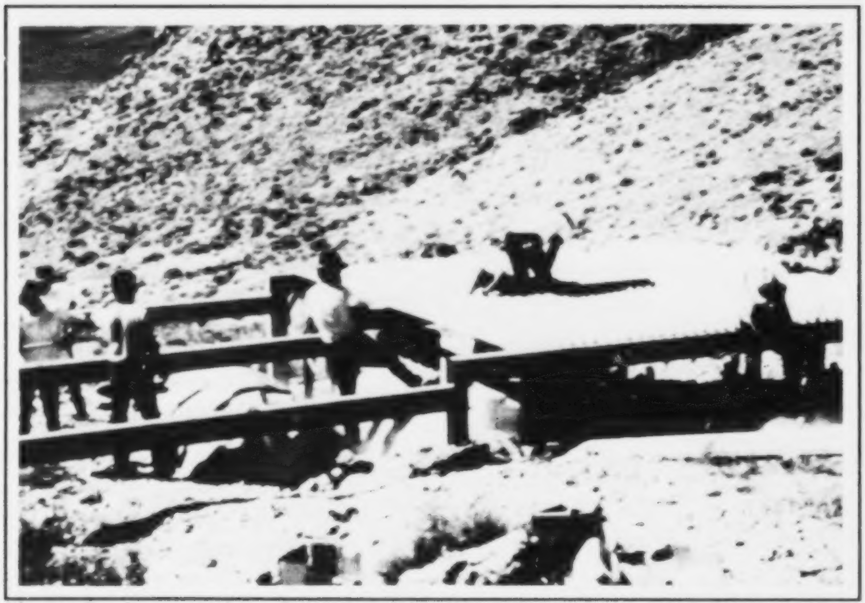

Figure 3. Construction of the Excelsior Big Game Guzzler with 32 ft. x 16 ft. canopy of 2 - 1350 gallon fiberglass water storage tanks.

built over the tanks. This tank depth may require a backhoe or blasting in rocky sites for the tank holes and the pipeline to the trough.

More and more interest is being shown in big game units in which the water is self leveling and requires no float or pressure valve which may turn into a maintenance problem. In one design we used five - 580 gallon steel livestock troughs plumbed together on a level site with 1 1/2 inch PVC pipe (or 1 1/4 inch poly pipe). The troughs required a interior frame to support covers (lids) so they could be buried. One trough extends out from underneath the 16 ft. by 32 ft. steel canopy 2 to 3 feet to provide the drinker (materials - $3,300). This design only requires digging to a depth of 20 inches. This design has worked well although we suspect rusting will reduce the life of this development. Care has to be taken to insure the plumbing between the tanks is below the frost line so that the lines are not broken.

In another design three - 900 gallon fiberglass upland game tanks are plumbed together (total capacity 2700 gallons) on a level site. As discussed above one of the units was extended out from underneath the steel canopy 2 to 3 feet to provide access to the drinker (materials - $3,400). This design requires a level area 16 feet by 32 feet and a depth of 30 inches.

A new design (utility patent pending) developed by Fiber Erectors is called a Parabolic Tank (material-$3,300) which stores approximately 2,100 gallons of water (also available as a 990 gallon upland game unit-$2,500). This modular design consists of two or four piece fiberglass tank which is 16 ft. to 20 ft. when it is bolted (and caulked) together at the site with a two or four piece lid. The lid or cover catches the water. The tank is bolted together upside down and then flipped over. When flipping the tank over care has to be taken not to damage the unit or risk hurting the construction crewt. The unit requires no plumbing, although care must be taken to insure the seams are properly caulked. All parts are light enough to be flown to a site by helicopter. The design requires a level area 16 to 20 feet in diameter. The tank is dug into a depth of 20 to 24 inches. Small game may enter the tank on a ramp to water. We modified this ramp to insure that small game could not fall into the tank. Big game drink directly from another opening in the tank lid. The opening may have to be modified if you feel that the antlers or horns of the animals are to large to get through the tank lid to drink. Care should be taken to remove material at the big game opening so the animals do not have to kneel to drink. This design may be modified so that a walk-in drinker can be attached and is the same depth thus requiring not float valve. This design requires 16 to 18 inches of rainfall to fill the storage tank. In the Carson City District we have had to add a supplemental 16 by 16 foot steel canopy (materials-$500) piped into the tank to fill these units (See Table 1 & Figure 4.). These type of units appear to collect more wind blown debris and the water appears to evaporate more rapidly because there is no canopy to shade the unit.

In a BLM wilderness study area (WSA) the guzzler will have to and meet the non-impairment criteria. This may influence the amount of surface disturbance allowed, the type of design and colors that are selected. For these reasons in coordination with the wilderness specialist we selected the parabolic design in a Carson City District wilderness study area.

CONCLUSION

The upland game guzzler design used by the BLM and Nevada Department of Wildlife in the BLM Carson City District is virtually maintenance free. This is a result of an all steel canopy construction and a one piece walk-in seamless fiberglass tank with no float or pressure valve required.

Because of the volume of water required (2,000 gallons or more), big game guzzlers will continue to have maintenance problems. These include plumbing between tanks and float or pressure valves in the trough or trough pipeline. The current trend is to develop self leveling water tanks to avoid these problems. However, current modular self leveling big game water tanks have less water holding capacity, collect wind blown debris, have increased evaporation, and leakage problems in the seams.

We feel a self leveling big game guzzler can be designed to surmount most of these problems. We would recommend a modular 2 to 4 piece fiberglass tank and lid 8 ft. x 20 ft. x 2.5 ft. with a walk-in drinker (8 ft. x 3 ft. x 2.5 ft.) attached directly to the side of the tank which would extend from underneath a 16 ft. x 32 ft. steel canopy. All of the parts of this design are light enough for helicopter transportation. This design will offer 2600 gallons of water storage (including drinker) while the steel canopy will provide shade to reduce evaporation.

Table 2. Guzzler Canopy Parts Used in the Carson City District.

	BLM	NDOW
Canopy Screw-Self Taping 3/16 in x 1 in. w/Seal	X 1/	
Canopy Bolts 1 in. x 1/4 in. Frame Bolts 1 in. x 3/8 in.	X	
Canopy Rivets		X
Precut 14 ga. Steel 3 in. x 8 in."C" Beams 6 ft.& 18 ft. Lengths for Canopy Frame	X	
Precut & Perforated 2 in. x 3 in.Angle Iron 5 ft. & 8 1/2 ft. lengths for Canopy Frame (325 gallon unit)		X
Precut & Perforated 2 in. x 3 in. Angle Iron 5 ft. & 15 ft. 3 in. lengths for Canopy Frame (900 gallon unit)		X
Corrugated 96 in. x 32 in. 22 ga. Steel Sheets (900 & 3000 Gallon Units)	X	
192 in. x 16 in. Interlocking 22 ga.Steel Sheets (900 gallon unit)		X
144 in. x 16 in. Interlocking 22 ga. Steel Sheets (325 gallon unit)		X

1/ One Canopy Carson City, Also Used BLM Winnemucca District

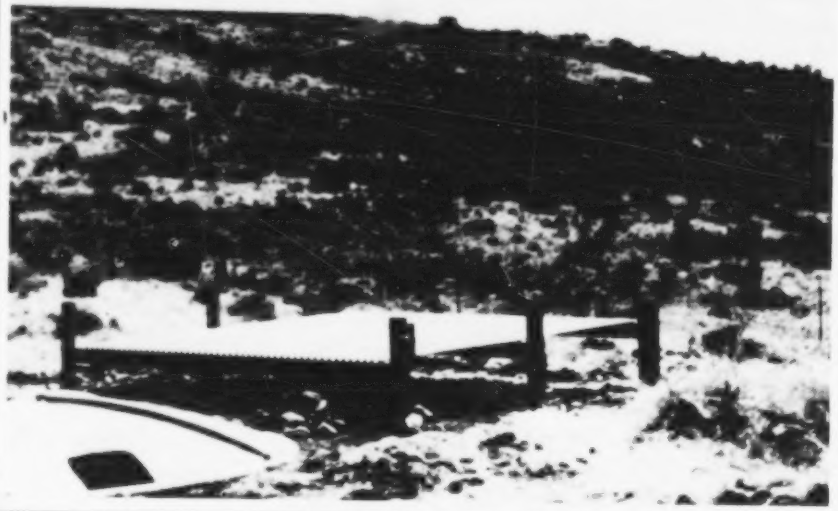

Figure 4. Big game parabolic (modular) 2,100 gallon fiberglass guzzler with 16 ft. x 16 ft. steel canopy.

Attachment 1. Known Suppliers of Guzzler Materials for the BLM and Nevada Department of Wildlife.

Fiberglass Tanks

Fiber Erectors Inc.
P.O.Box 1009
Red Bluff, Ca. 96080

Fiberglass Systems Inc.
1080 W. Amity Road
Boise, Id 83705

Industrial Fiberglass Boats
2687 Industrial Road
Las Vegas, Nevada 89109

Fiberstrong, Inc.
202 Albany
Caldwell, Id. 83605

MNK Enterprises
10 So. 1st East
Bancroft, Id. 83217

Lifetime Fiberglass Tank Co.
5000 Packing House Road
Denver, Colo. 80216

Steel Tanks

Nevada Bearing & Fabrication
651 River St.
Elko, Nv. 89801

Oak Street Tank & Steel, Inc.
P.O. Box 850
Ashland, Or. 97520

Rule Steel Tanks, Inc.
Route 3, Box 80
Caldwell, Id. 83605

SG Welding & Mfg.
Rt. 4, Box 399
Buhl, Id. 83316

Walton Underground Systems
702 19th St.
Rupert, Id. 83350

Plastic or Polyester Liners

Palco Linings, Inc.
7571 Santa Rita Circle
Stanton, Ca. 90680-0919

Watersaver Company, Inc.
P.O.Box 16465
Denver, Colo. 80216

Gundle Lining Systems Inc.
1340 E. Richey Road
Houston, Texas 77073

Titan Rubber & Supply Co.
1375 E. 2nd
San Jose, Calif. 95112

Angle Iron

PDM Service Center
1250 Cleppe
Sparks, Nev. 89431

Steel Sheeting/Corrugated Metal

Curoco
536 Cleveland Ave.
Albany, Ca. 94710

George F Kaelp Const. Co.
3250 Spring Mtn. Road
Las Vegas, Nev. 89102

Galvanized Gutter

Ames - Frey Co.
1414 Adelia Ave.
So. El Monte, Calif. 91733

A SUMMARY OF IDAHO'S WILDLIFE WATER DEVELOPMENTS AND WILDLIFE USE OF GUZZLERS IN SOUTHEASTERN IDAHO

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Abstract

A survey of Bureau of Land Management and United States Forest Service personnel in the southern part of Idaho was conducted to ascertain numbers, types and qualities of water developments installed for wildlife in the last ten years. Ponds, dugouts, and catchments were the most frequently used techniques, followed by 500 gallon guzzlers, spring improvements and 1000 gallon guzzlers and other techniques. Preferred designs (in order of satisfaction) were: 500 gallon guzzlers, ponds, spring improvements and "flying saucer" guzzlers.

Wildlife use of guzzlers in the Big Desert area in southeastern Idaho is also evaluated. Pronghorn antelope (Antilocapra americana) most frequently used these guzzlers, followed by mourning dove (Zenaidura macroura), sage grouse (Centrocercus urophasianus) and passerine species.

INTRODUCTION

As part of the Habitat Improvement Program, the Department of Fish and Game is developing preferred guidelines for the construction and placement of wildlife guzzlers and similar structures for pheasant (Phasianus spp.), valley quail (Lophortyx californicus), chukar (Alectoris chukar), and gray partridge (Perdix perdix).

Water development is a commonly used technique to enhance wildlife habitat in areas with no or ephemeral water sources (Yoakum 1980, McCarty, 1986). Little published information exists to document the construction and maintenance problems associated with current designs or quantitative evaluation of wildlife use of water developments in Idaho. The need for this kind of information was the basis for this paper.

METHODS

To help determine the best types of structures for our purposes, a questionnaire for land management agencies in Southern Idaho was compiled (Appendix A). The form was sent to the wildlife biologists, or equivalents, at all National Forest and BLM districts in the southern two-thirds of the state.

Of 33 questionnaires sent out, 22 were returned and the information therein is compiled and summarized in this paper.

Only structures or developments designed specifically to benefit wildlife were evaluated. Livestock water developments that may have also provided water for wildlife were excluded to minimize response time and ease reporting requirements of the respondents. The questionnaire was designed to be quite subjective to allow local biologists to respond with opinions and suggestions whenever possible.

Wildlife use at guzzlers in the Big Desert area of Southeastern Idaho is also reported. Techniques utilized in this study involved clearing approaches to guzzler ramps and periodically checking for tracks, droppings, and feathers to evaluate wildlife use. A more detailed report of techniques is reported in a paper entitled "Sage Grouse Use of Wildlife Water Developments in Southeastern Idaho" (by Connelly and Doughty) in these proceedings.

RESULTS

A total of 494 wildlife water developments were reported constructed between 1978-1988 by the respondents. The most common water development was construction of ponds, dugputs, and catchments.

A 500 gallon guzzler tank with one of three collector apron designs (12' x 12', "butterfly" double 12' x 12', or 4' x 40' [Person, et.al 1969, Roberts, 1969,]) were the second most frequently constructed facility. Spring improvements were the next most commonly used techniques. They included cleaning livestock-trampled water sources, fencing, and piping livestock water to troughs outside of exclosures.

One thousand gallon storage tank guzzlers with either square or 4' x 40' collector aprons were the next most frequently used, followed by Fiber Erector "Flying Saucers" (P.O. Box 1009, Red Bluff, CA. 96080). Livestock water pipeline sources to feed wildlife storage tanks, wells operated to fill storage tanks and troughs for wildlife , and beaver transplants and beaver dam reconstruction were less frequently utilized techniques.

When asked what developments have worked the best and why, the respondents favored the 500 gallon, ramp-accessed type with a collector apron followed by ponds, dugouts and catchments, spring developments, and the flying saucer guzzlers. These designs were preferred mainly because of the low maintenance required for operation.

The most commonly encountered maintenance problems involved operation of pipelines and valves (especially pressure sensitive types); damage to collector aprons from trampling by livestock and big game, improper apron construction and damage as a result of heavy snow pack on the aprons. Other less frequently reported problems included fiberglass holding tank cracks and breakage due to trampling by big game, fence maintenance and poor water quality following periods without precipitation.

Designs to be avoided included structures utilizing livestock water pipelines as a supply source; designs that utilized valves, floats, etc. and storage tanks with inadequate capacity for big game.

Because of the wide variety of habitats on which development projects have been attempted, responses to the questions involving wildlife species benefitted by projects were varied. Respondents felt that approximately 75% of the projects have received significant wildlife use and that big game (mule deer [Odocoileus hemionus], elk [Cervus eplaphus], antelope, bighorn sheep [Ovis spp.] and moose [Alces alces]) were the most common users of the facilities, followed by game birds (sage grouse, chukar, forest grouse [Dendragapus and Bonasa sp.] mourning dove, grey partridge, turkey [Meleagris gallopavo], and pheasant); non-game birds; non-game mammals; rodents and reptiles. Species believed to have most benefited from the developments were game birds (sage grouse, chukar, mourning dove, forest grouse, grey partridge, turkey, pheasant, and waterfowl); big game (deer, elk, antelope, and moose); non-game birds and non-game mammals.

The sage grouse research project reported by Connelly and Doughty in these proceedings also produced data on other species using guzzlers in the Big Desert in Southeastern Idaho. In a total of 179 checks, there were a total of 511 visits by fourteen species or types of wildlife (passerine birds, rodents, etc. could not be identified as to species) as depicted in Table I.

DISCUSSION

Analysis of the survey responses indicated the following:

1. Whenever extension of the period of availability of water in intermittent or ephemeral sources is the objective of the project, improving existing water sources with storage tanks, catchments, etc. should be the preferred technique.

2. Guzzlers will provide satisfactory results if the following guidelines are followed:

    A. 500 gallon storage is generally adequate for small game, 1000 gallon storage is necessary for antelope and deer, and large capacity (2500 gallon) is required if elk use is anticipated. Fiberglass storage tanks should be of highest quality and closely inspected before use to detect cracks, thin areas, etc.

Table I. Wildlife use at guzzlers in the Big Desert of Southwestern, Idaho.

SPECIES	(1)	(2)	(3)	SPECIES	(1)	(2)	(3)
Mourning Dove	107	20.9	59.8	Antelope	137	26.9	765
Sage Grouse	76	14.9	42.5	Elk	36	7.0	201
Passerine spp.	60	11.7	33.5	Coyote	38	7.4	212
Corvid spp.	12	2.3	6.7	Bobcat	10	2.0	56
Raptor spp.	7	1.3	3.9	Badger	7	1.3	39
Rodent spp.	16	3.1	8.9	Least Weasel	3	0.6	17
Rept. (lizard)	1	0.1	0.5	Mule Deer	2	0.4	11
				TOTAL	511	100%	100%

(1) Tally of sign of this species being present at the guzzlers during the census period.
(2) Frequency (in percent) of total wildlife visits during the census period (N = 511).
(3) Frequency (in percent) that this species had visited during the census period (N = 179).

B. Collector aprons should be designed to collect adequate water during low precipitation periods (drought) i.e. collection surface should ideally be greater than what is prescribed for average precipitation.

C. Apron shape does not appear to matter as long as the slope to the storage tank is correct (not too steep), however, some respondents felt the "butterfly" collector may inhibit vision of big game and detract from potential use by these species. Suggestions to reduce apron damage by trampling included interior fencing and piling brush around the edges to deter access. High quality lumber and galvanized nails should be used in apron construction.

D. Where big game use is anticipated, the access ramp should be supported to alleviate breakage.

3. Flying saucer guzzlers were reported to be easy to install but access to water by big game may be restricted if less than 85% full and fiberglass breaks may occur if accessible to elk.

On the Big Desert in Southeast Idaho, the following conclusions can be made from the research by Connelly:

Installation of these guzzlers may have resulted in establishment of summering elk herds where none existed previously. Activities of these elk have necessitated higher than expected maintenance, the need for supplemental watering and various other problems. Future guzzlers should be of much larger capacity and heavier construction in an attempt to correct these problems.

The frequency of use by mule deer was under-reported with this technique because deer tracks and signs were impossible to reliably differentiate from evidence of antelope use. Mule deer use is believed to be much higher than the 1.1% reported.

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Roberts, R.F., 1969. Big game guzzlers. Range Man's Journal. Vol. 4 No. 3: 80-82.

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APPENDIX A.

THE WILDLIFE WATERING FACILITY QUESTIONNAIRE

1. How many projects aimed specifically at improving or providing water sources for wildlife have you completed in the last ten (10) years?

2. What types of projects were involved (guzzler designs, catchment types, bentonite, etc.)?

3. What types of wildlife used the structures?

4. What percentage of the structures received significant wildlife use?

5. What species benefitted the most?

6. What designs have worked best and why?

7. What designs should be avoided and why?

8. What advice can you provide regarding placement (near natural water, where no free water is available, etc.)?

9. What maintenance problems have you identified?

10. What other problems have you encountered (damage by big game on upland guzzlers, ambush sites for hunters, vandalism, etc.)?

11. What would you recommend to reduce these problems?

Cost/Benefit

USE OF THE BUREAU OF LAND MANAGEMENT'S PRODUCTIVITY ANALYSIS PROCEDURE TO EVALUATE BENEFITS AND COST OF WILDLIFE WATER DEVELOPMENTS

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Abstract

Traditionally the effects of proposed actions were looked at in the context of the situation before the action and the effects after. Rather than use this comparison, the Bureau of Land Management's Wildlife/Fisheries Productivity Analysis compares effects with and without the action. This approach allows the resource specialist to consider habitat trends that are occurring independently of the proposed action. Wildlife/Fisheries Productivity Analysis also provides the resource specialist documentation of their thought processes without requiring judgment of the economic value of changes in population numbers.

INTRODUCTION

Section 202(c)(2) of the Federal Land Policy Management Act states in-part:

> "Use a systematic, interdisciplinary approach to... integrate... physical, biological, economic and other sciences."

Integration of biological and economic sciences into rangeland management emphasized the need for wildlife productivity analysis. Without productivity analysis the wildlife biologist will not be able to document their thought processes when reviewing proposed actions.

The Bureau of Land Management (BLM) in developing Wildlife/Fisheries Productivity Analysis (WFPA) took the necessary step beyond the traditional before and after analysis. In the before and after analysis (Figure 1) productivity for a representative species has a value of P_1 before the proposed action and value of P_2 after the action at time T_2. Traditionally the change in productivity (P) is seen as P_2-P_1.

In the "with and without" analysis of WFPA (Figure 2) productivity for a species still has a value of P_1 before the action and P_2 after at time T_2. We must, however, estimate a value for P_3, the productivity at time T_2, without the action. With this approach the change in productivity (P) is P_2-P_3, not P_2-P_1.

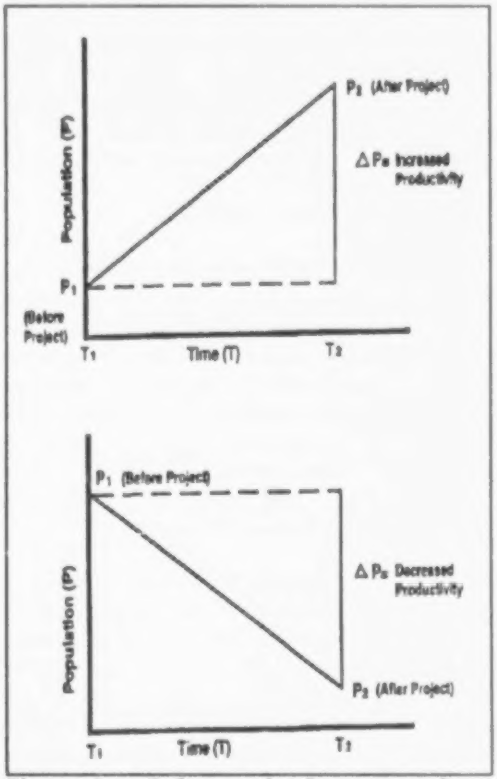

Figure 1. Before and after approach to determining changes in a population with a project.

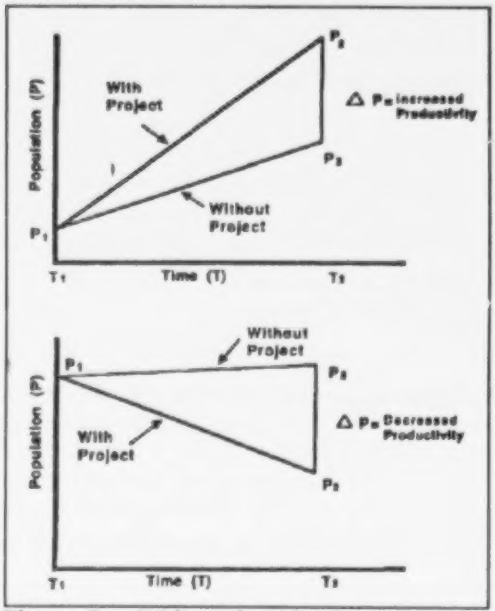

Figure 2. With and without approach to determining changes in population with a planned project.

The change in productivity shown with WFPA better represents what really happens in wildlife habitats, which are rarely in a static condition. Whether or not a proposed action takes place, some habitat factors will be changing.

REQUIREMENTS

Leopold (1933) placed the factors that affect a wildlife population into two categories. The first category were decimating factors - these that kill animals directly but are not habitat factors. These include hunting, predators, starvation, diseases, parasites, and accidents. The influence of decimating factors must be considered. Their possible impacts on the population in question should be documented in the worksheet section for assumptions.

Leopold listed the second category as welfare factors - these that operate indirectly by decreasing the reproductive rate and weakening the defense against the decimating factors. Welfare factors, in WFPA terminology, are the habitat factors. These include nonlethal shortages of food, water, cover and special requirements such as human disturbance. One or more of these habitat factors will always be less than optimal

Specialists should use detailed factors within the broad categories of food, water, cover and space. Particularly when a detailed factor will have a definite impact on the population. An example of this is the proximity of domestic sheep to bighorn sheep under the broad category of space.

WFPA also requires that specific population data and it's sources are documented. This allows others to evaluate this data. If there is disagreement, perhaps those who disagree will know the source of more accurate information. Because all such data are subject to sampling error, the specialist is not expected to be totally correct but only to document the best existing information. If the best information is based only on professional judgment, then that is the starting point.

METHODS

In order to better understand WFPA we will follow the steps taken to analyze an actual proposed action. Four Table Mountain Guzzlers were proposed in the North Stillwater Range Habitat Management Plan (HMP) covering terrestrial Wildlife Habitat Area number 16 (WHA-T-16). Desert bighorn sheep (Ovis canadensis nelsoni) are to be reintroduced into the area. Some movement into the area from the south by bighorns has been reported but unconfirmed.

In order to document the process of analysis we first use the WFPA Limiting Factors Worksheet (Figure 3). Section A "Proposed Action Analysis" allows the wildlife biologist or other specialist the opportunity to quickly look at the overall impacts of the proposed action on the habitat factors. The Habitat Factors - Limiting Factor Analysis (section B) allows for the detailed analysis of not only the broad categories but the more detailed factors. Habitat Rating must be recorded as percent of optimum. Current ratings for Figure 3 were taken from field inventory data using Armentrout and Brigham, 1988. Without Action habitat ratings were provided through a "what if" analysis of the inventory data and analysis. With Action habitat ratings were calculated using the "what if" analysis should the proposed action be completed. It should be noted that habitat factors other than water will also be impacted by the proposed action while some factors are not.

Under the Current and Without Action scenarios water is the most limiting factor. If the proposed action is completed cover becomes the limiting factor. Use of the limiting factor approach allows for an ecological rather than a desired result analysis of the action.

The Optimum Population Level (Figure 4) is based on the analysis completed within the HMP and a prescribed optimum density of 4 bighorns per square mile. Population and Harvest Analysis is self evident in Figure 4. The Percent of Population that can be harvested was calculated from information provided in Delaney, 1988. The Number of Years After Completion of Action and Without Action to Realize change in Population are professional judgment based on follow-up reports of reintroductions completed by the Nevada Department of Wildlife (NDOW) in similar habitats.

The Hunter (User) Day Calculations For Use with WFPA Limiting Factors Worksheet (Figure 5) was completed using data from Delaney, 1988. You will note the signature blocks on this and the WFPA worksheet. In some cases a resource specialist other than the wildlife biologist may complete these worksheets. Wildlife concurrence, however, is required for the data to be acceptable for benefit/cost analysis.

Hunter (User) Day Calculations For SAGERAM (Figure 6) are the final Figures used in the BLM's rangeland benefit/cost analysis. When reviewing the figures we can see the proposed action will only double the hunter days which can be achieved without the action. At first glance this may not seem like much, but when we see it will take 49 years to reach the hunter use days projected without action to 15 years with the action we get a better feel for the benefit/cost results.

CONCLUSIONS

Wildlife/Fisheries Productivity Analysis forces us to think critically about our assumptions, which otherwise are often neither stated or recognized. Once the assumptions are documented for the wildlife biologist and others to evaluate, the whole analysis might be improved.

The traditional use of before and after analysis is superceded by the more accurate "with and without" analysis. This use of the latter analysis provides us with the opportunity to preview tile impacts of a proposed action as a whole.

Finally, WFPA provides us with a tool to help integrate biological and economic sciences in multiple use management.

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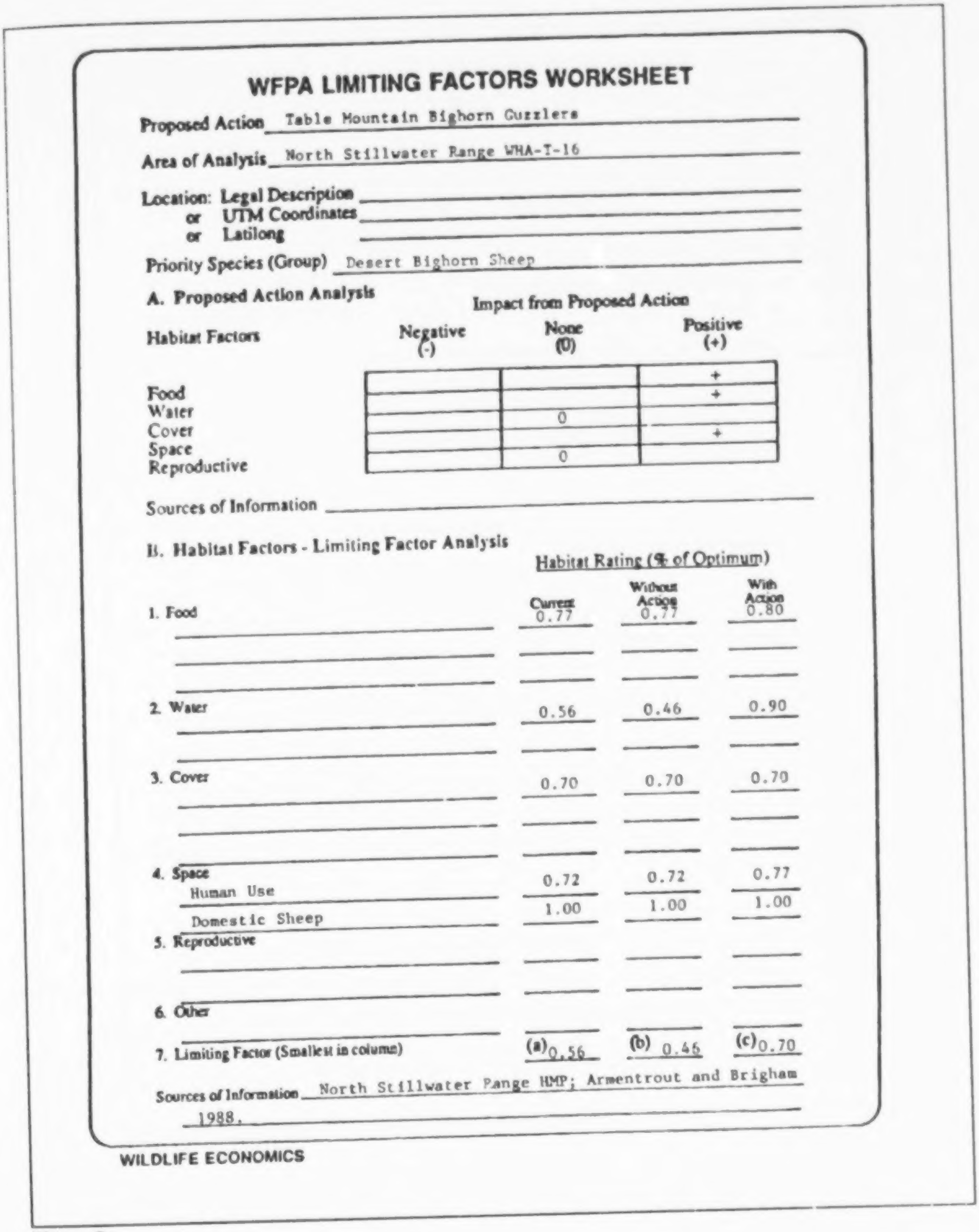


WFPA LIMITING FACTORS WORKSHEET

Proposed Action Table Mountain Bighorn Guzzlers

Area of Analysis North Stillwater Range WHA-T-16

Location: Legal Description
or UTM Coordinates
or Latilong

Priority Species (Group) Desert Bighorn Sheep

A. Proposed Action Analysis

Impact from Proposed Action

Habitat Factors	Negative (-)	None (0)	Positive (+)
Food			+
Water			+
Cover		0	
Space			+
Reproductive		0	

Sources of Information

B. Habitat Factors - Limiting Factor Analysis

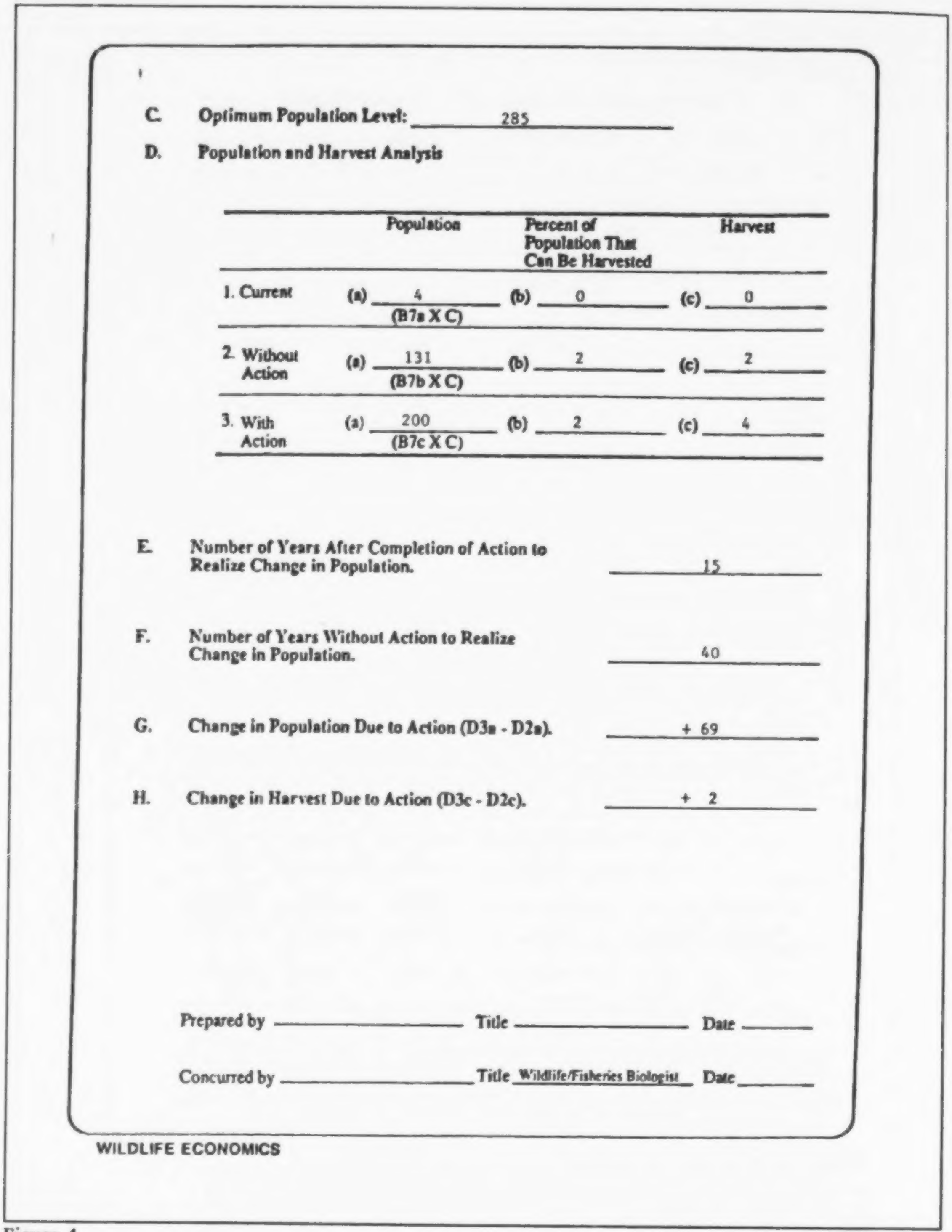
Habitat Rating (% of Optimum)

	Current	Without Action	With Action
1. Food	0.77	0.77	0.80
2. Water	0.56	0.46	0.90
3. Cover	0.70	0.70	0.70
4. Space			
Human Use	0.72	0.72	0.77
Domestic Sheep	1.00	1.00	1.00
5. Reproductive			
6. Other			
7. Limiting Factor (Smallest in column)	(a) 0.56	(b) 0.46	(c) 0.70

Sources of Information North Stillwater Range HMP; Armentrout and Brigham 1988.

WILDLIFE ECONOMICS

Figure 3.



C. **Optimum Population Level:** 285

D. **Population and Harvest Analysis**

	Population	Percent of Population That Can Be Harvested	Harvest
1. Current	(a) 4 (B7a X C)	(b) 0	(c) 0
2. Without Action	(a) 131 (B7b X C)	(b) 2	(c) 2
3. With Action	(a) 200 (B7c X C)	(b) 2	(c) 4

E. **Number of Years After Completion of Action to Realize Change in Population.** 15

F. **Number of Years Without Action to Realize Change in Population.** 40

G. **Change in Population Due to Action (D3a - D2a).** + 69

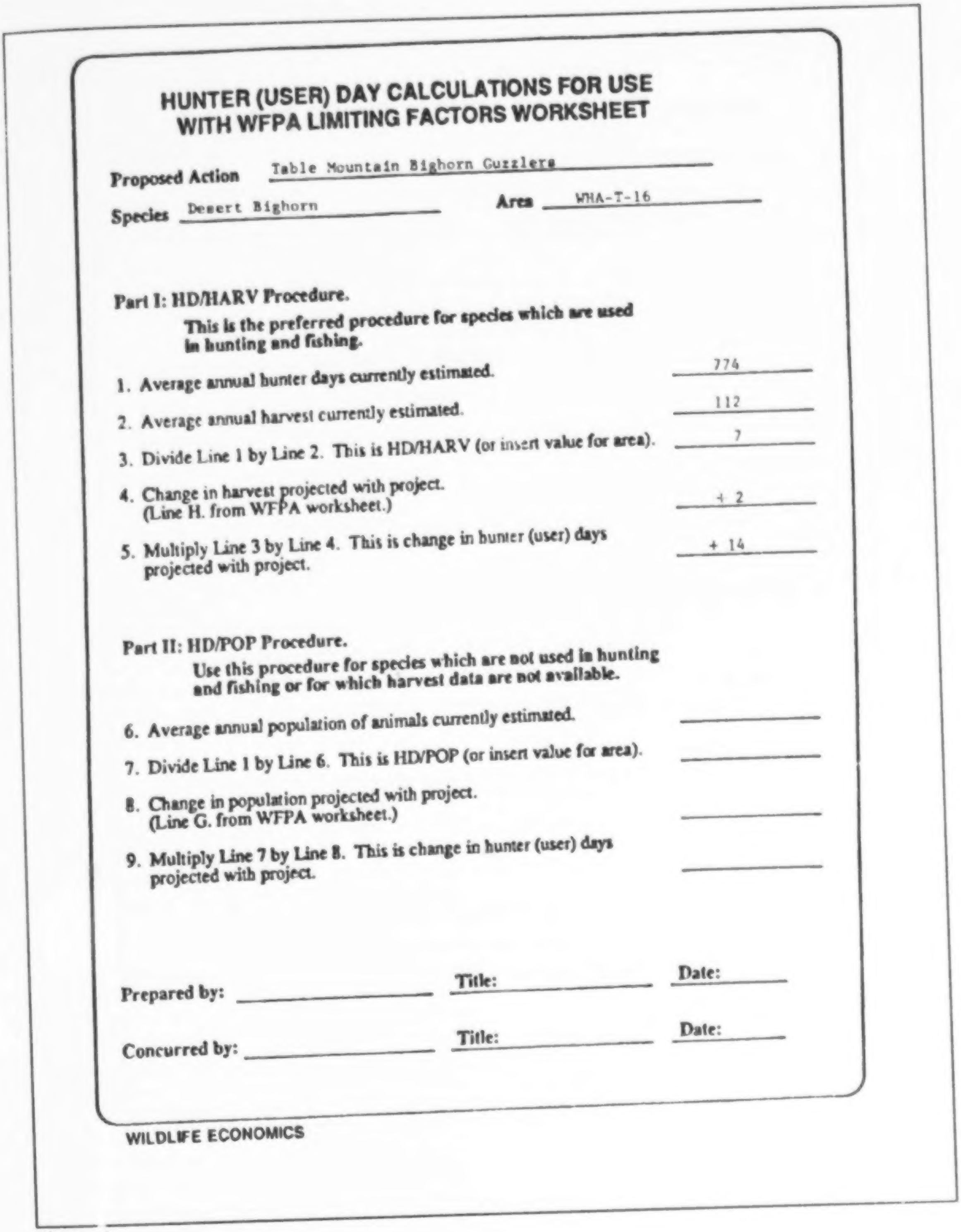
H. **Change in Harvest Due to Action (D3c - D2c).** + 2

Prepared by ____________ Title ____________ Date ______

Concurred by ____________ Title Wildlife/Fisheries Biologist Date ______

WILDLIFE ECONOMICS

Figure 4.



HUNTER (USER) DAY CALCULATIONS FOR USE WITH WFPA LIMITING FACTORS WORKSHEET

Proposed Action Table Mountain Bighorn Guzzlers

Species Desert Bighorn **Area** WHA-T-16

Part I: HD/HARV Procedure.

This is the preferred procedure for species which are used in hunting and fishing.

1. Average annual hunter days currently estimated. 774
2. Average annual harvest currently estimated. 112
3. Divide Line 1 by Line 2. This is HD/HARV (or insert value for area). 7
4. Change in harvest projected with project. (Line H. from WFPA worksheet.) + 2
5. Multiply Line 3 by Line 4. This is change in hunter (user) days projected with project. + 14

Part II: HD/POP Procedure.

Use this procedure for species which are not used in hunting and fishing or for which harvest data are not available.

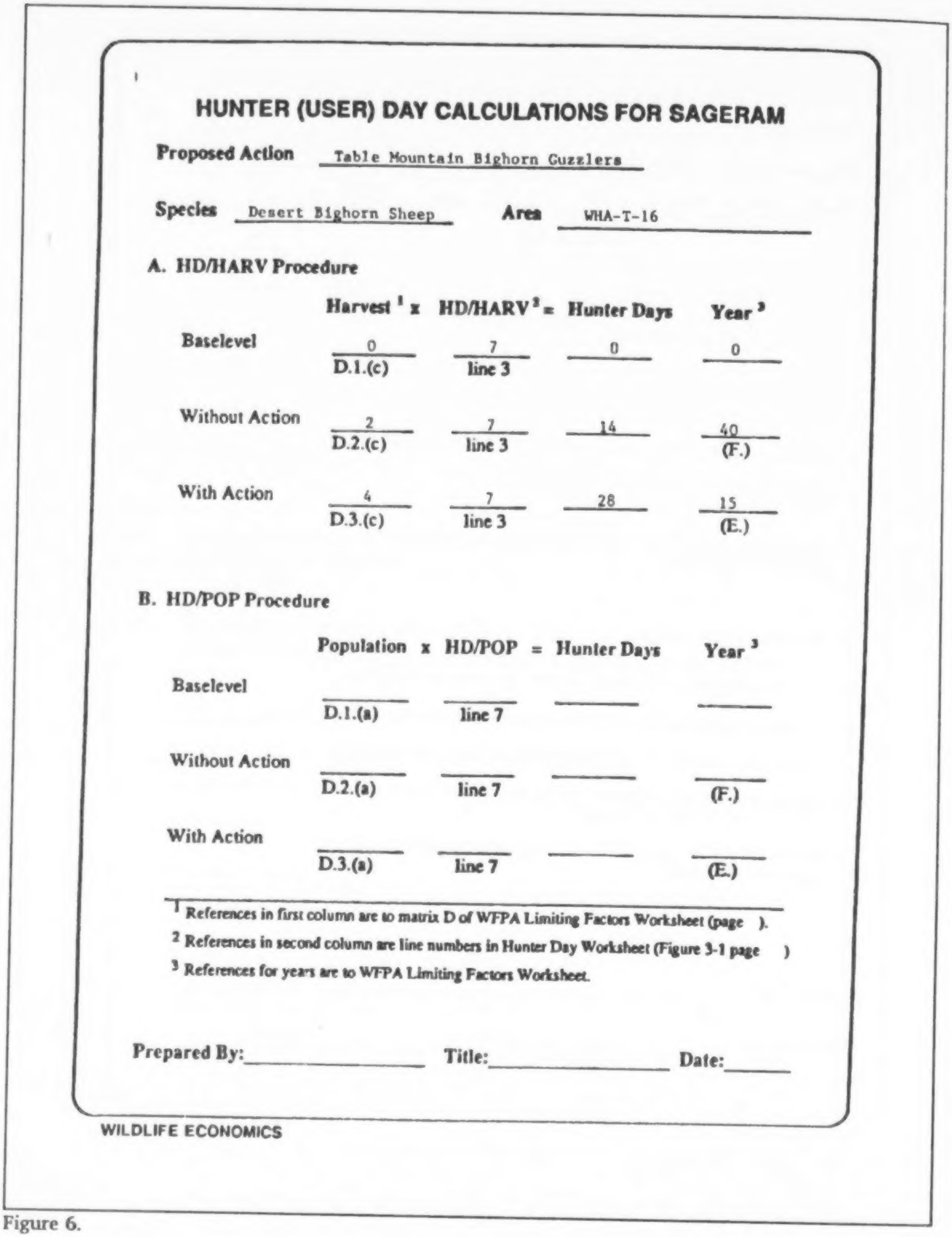
6. Average annual population of animals currently estimated. ______
7. Divide Line 1 by Line 6. This is HD/POP (or insert value for area). ______
8. Change in population projected with project. (Line G. from WFPA worksheet.) ______
9. Multiply Line 7 by Line 8. This is change in hunter (user) days projected with project. ______

Prepared by: ______ **Title:** ______ **Date:** ______

Concurred by: ______ **Title:** ______ **Date:** ______

WILDLIFE ECONOMICS

Figure 5.



HUNTER (USER) DAY CALCULATIONS FOR SAGERAM

Proposed Action Table Mountain Bighorn Guzzlers

Species Desert Bighorn Sheep **Area** WHA-T-16

A. HD/HARV Procedure

	Harvest[1] x	HD/HARV[2] =	Hunter Days	Year[3]
Baselevel	0 D.1.(c)	7 line 3	0	0
Without Action	2 D.2.(c)	7 line 3	14	40 (F.)
With Action	4 D.3.(c)	7 line 3	28	15 (E.)

B. HD/POP Procedure

	Population x	HD/POP =	Hunter Days	Year[3]
Baselevel	D.1.(a)	line 7		
Without Action	D.2.(a)	line 7		(F.)
With Action	D.3.(a)	line 7		(E.)

---

[1] References in first column are to matrix D of WFPA Limiting Factors Worksheet (page).

[2] References in second column are line numbers in Hunter Day Worksheet (Figure 3-1 page)

[3] References for years are to WFPA Limiting Factors Worksheet.

Prepared By:______________ **Title:**______________ **Date:**______

WILDLIFE ECONOMICS

Figure 6.

A HISTORIC REVIEW OF ARIZONA'S WATER DEVELOPMENTS WITH DISCUSSIONS ON BENEFITS TO WILDLIFE, WATER QUALITY AND DESIGN CONSIDERATIONS

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Abstract

Water development to benefit wildlife has become a major commitment by resource managing agencies in the Southwest. Few studies have been completed documenting a relationship between building additional waters and increased wildlife. We reviewed historic population data measured as number of hunters and harvest of mule deer in 2 units with very low deer populations. In both units, there was an apparent increase in deer numbers due to catchment construction. We also discuss changes in movement patterns for Sonoran pronghorn and desert bighorn ostensibly associated with water development. Concerns of water quality are discussed.

INTRODUCTION

The issue of whether to build water developments to benefit wildlife is a question that is debated by various resource managers. The hypothesis that an increase in the number of water sources can benefit ungulate populations assumes that water is a primary factor limiting utilization of an area during the dry season.

Some researchers indicate that water placement is important to determining habitat suitability for desert bighorn sheep (Ovis canadensis nelsoni and O. c. mexicana). Most habitat evaluation models used today indicate that water is important in determining habitat suitability for desert bighorn (Ferrier and Bradley 1970, Wilson et al. 1980, Cunningham et al. 1987). Yet some researchers indicate that there are bighorn herds which exist totally without free-standing water (Watts 1979, Krausman et al. 1985).

Conflicts over the need for free water exists between researchers on other desert ungulates. Monson (1968) maintains that Sonoran pronghorn (Artilocapra americana sonoriensis) may never utilize water even though it may be available. He concludes "there is no point in developing water specifically for these animals." This was based on 7 years (1955-62) of observation while in the capacity of Refuge Manager on the Cabeza Prieta National Wildlife Refuge. More recently, Sonoran pronghorn research conducted by Arizone Game and Fish Department (AGFD) indicate that available water may be a limiting factor and water development can be used to enhance recovery potential (Wright and deVos, 1986). Further confusing the issue of building water catchments to benefit wildlife are concerns that water developments may benefit predators to a greater extent than the target animals (Natural Resources Planning Team, 1986).

In spite of apparent conflict in the literature, development of water sources has become a major segment of wildlife management programs in most southwestern states. Development construction by AGFD began in 1946, when 18 "gallinaceous guzzlers" were built (Schadle, 1958). Construction of water developments has continued unabated. The fiscal year 1988-89 Work Plan for development and maintenance of water sources indicated that AGFD will be responsible for maintaining approximately 725 water sites this year. Costs for maintenance during the current year is $753,000. This will fund construction of 8 new rainwater catchments and development of 8 potholes or springs (AGFD, 1988). Construction of wildlife water catchments is an accepted form of mitigation to offset loss of habitat or bisecting movement corridors as a result of major water movement projects (deVos et al. 1982).

Although development of water sources represents a major commitment of both funds and labor, much of the literature fails to prove a cause and effect relationship between additional water sources and increased wildlife populations. Few if any systematic, before and after, studies documenting this relationship exist. We review historic population trend data measured as number of hunters and harvest of mule deer (*Odocolious hemionus*) in 2 low desert units in southwestern Arizona in relation to water development and precipitation patterns. We also discuss changes in seasonal movement and habitat use patterns of bighorn sheep ostensibly associated with water development. Water development structural and hydraulic design considerations and water quality parameters of tinajas and retention dam developments in the study area were also addressed.

STUDY AREA

The study area is in the Sonoran Desert, one of the most complex deserts in the United States (Brown 1982). The vegetation of the area is an assembly of drought adapted subtropical species. Shreve and Wiggins (1964) recognize several subdivisions in this desert; two of which (Arizona Upland and Lower Colorado River Valley) are present on this study site. The Colorado River Valley subdivision occurs in much of the study area. The most widespread plant association is creosote (*Larrea tridentata*) - white bursage (*Ambrosia dumosa*) (Brown 1982). Vegetation in this community is typically sparse.

The Arizona Upland subdivision is found in the eastern portion of the study area and in mountainous locations. Vegetation is more dense than in the LCRV subdivision and is dominated by palo verde (*Cercidium floridum* and *C. microphyllum*) mesquite (*Prosopis juliflora*) ironwood (*Olneya tesota*) and saguaro (*Carnegiea giganteus*) (Wright and deVos 1986).

This area is typified by extreme temperature ranges of up to 44°C in summer and occasionally below 0°C in winter. Rainfall is bimodal with peaks in late summer and winter. May and June are typically the driest months (Sellers and Hill 1974). Topography is that of the Basin and Range physiographic province of southwestern U.S. and northern Mexico (Nations and Stump 1981).

Naturally occurring free-standing water is limited to scarce, semi-permanent ephemeral tinajas and springs located in bedrock areas, and the Gila River which flows intermittently near the southern border of Unit 41. These supplies have been supplemented in the last 40 years by addition of groundwater developments and rainwater catchments placed primarily in alluvial areas, and retention dam/tinaja developments in intermittently dry mountainous areas.

METHODS

Two Game Management Units (Units 40-41) were selected for evaluation (Fig. 1). Both had an extremely low mule deer population prior to construction of developments in each. Harvest and hunter density estimates for the period 1960-1970 were correlated with the number of water sites available. Changes in habitat use by pronghorn and bighorn sheep were documented during radio telemetry studies and by direct observation.

Precipitation records were compiled from Sellers and Hill (1974) and the Arizona StateUniversity Laboratory of Climatology for two stations near the eastern and western boundaries of the study area; Gila Bend and Wellton, respectively. Regression slopes of annual rainfall between 1948-1985 were calculated to determine long-term precipitation trends. The history of

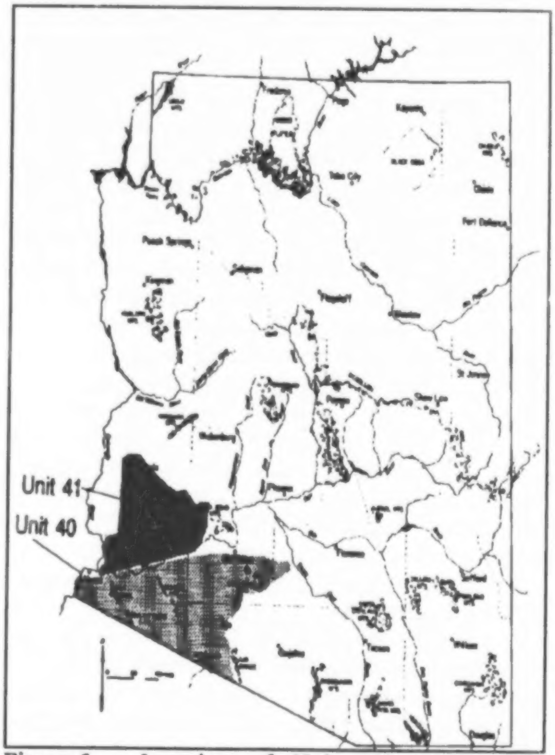

Figure 1. Location of Units 40 and 41 in Southwestern Arizona

water development construction within the Units were compiled from AGFD records.

Mule deer hunter harvest, hunter numbers, and hunter success rates for the period 1960-70 were obtained from AGFD files for Units 40 and 41. These parameters were compared to precipitation trends and cumulative numbers of water developments in each unit. We selected this time frame of study based upon recommendations by Remington et al. (1984). They found that deer use of a catchment increased each year during a three year study and recommended that developments to offset the adverse impacts from projects would require at least two years to be effective.

Water quality analyses were performed with the following equipment: **Conductivity**-Amber Science Model 604, 500 Series temperature compensated conductivity meter; **pH**-VWR Scientific Inc. Model 47 Mini-pH meter; **Dissolved Oxygen**-Bausch and Lomb SpectroKit Reagent System for Dissolved Oxygen (Catalog No. 330908-titration method); **Alkalinity**-Bausch and Lomb SpectroKit Reagent System for Alkalinity as Calcium Carbonate (Catalog No. 330901); **Nitrogen (Nitrate)**-Bausch and Lomb SpectroKit Reagent System for Nitrogen (Nitrate) (Catalog No. 330906-cadmium reduction method) using a Bausch and Lomb Spectronic mini 20 spectrophotometer; **Orthophosphate**-Bausch and Lomb SpectroKit Reagent System for Phosphate (Ortho) (Catalog No. 330909-scorbic acid method) using a Bausch and Lomb Spectronic mini 20 spectrophotometer.

Equipment was field calibrated using known reference solutions (conductivity, pH) or reagent blanks (nitrogen [nitrate] and orthophosphate). Nutrient spectrophotometer absorbance readings were converted to mg/l using standard curves determined in the lab for the unit.

Surface area at a site was determined by the product of mean length and mean width and rounded to the nearest .9 m^2. Capacity was determined by the product of mean length, mean width and mean depth and converted to the nearest 380 liters. Elevations were determined from topographical maps.

RESULTS

During the period of 1960-70, the number of hunters ranged from 132 (1960) to 810 (1970) in Unit 40. In Unit 41, the estimated number of hunters ranged from 380 (1960) to 2,338 (1970) (Fig. 2). Both of these represent approximately a six-fold increase in the 11 year period. Harvest ranged from 0 (1960) to 120 (1967) in Unit 40 while ranging from 62 (1960) to 319 (1969) in Unit 41 (Fig. 3). Statewide hunter success declined from 36.9% to 16.3% from 1960-70. Hunter success rates were highly variable in Unit 40 over this period, but remained relatively constant in Unit 41 (Fig. 4).

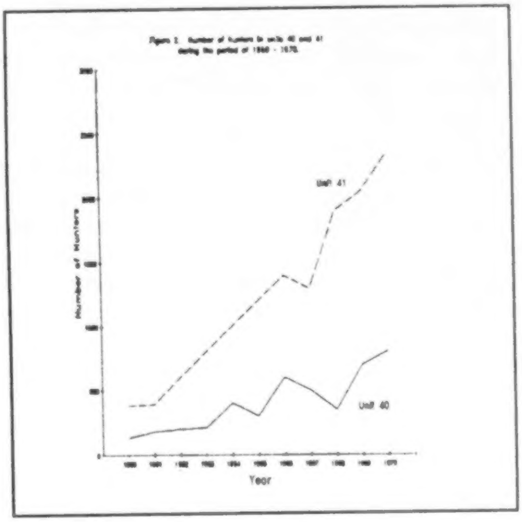
Figure 2. Number of hunters in units 40 and 41 during the period of 1960 - 1970.

The long-term precipitation trend from the Wellton and Gila Bend weather stations was positively sloped over the 1948-85 period. However, annual levels were above the regression line in only four years of the 11 year period of interest for both stations (Fig. 5). Construction of water developments within Units 40 and 41 reached 15 and 17, respectively, by 1960, and rose to 34 and 31 by 1970.

Water quality and site dimensional parameters for selected wildlife water

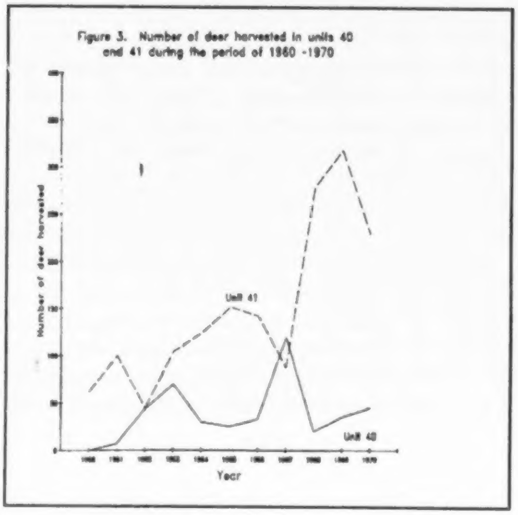
Figure 3. Number of deer harvested in units 40 and 41 during the period of 1960 -1970

developments are in Table 1. Site elevations of the sampled tinaja and retention dam developments in the Lower Gila River Drainage ranged from 271-927 m. Surface areas at full capacity were between 4.7-37.2 m^2 and maximum capacities ranged from 2650-49,205 liters. Sites surveyed during summer months exhibited surface water temperatures of 20.0-31.0°C, and those sampled in winter were between 7.5-9.5°C. Conductivity readings were relatively uniform among waters, varying between 133-887 uS/cm,indicating little salinity problems. Hydrogen ion potentials (pH) ranged from 6.3-9.3, with most around 7-8. Alkalinity levels indicated most waters were well buffered.

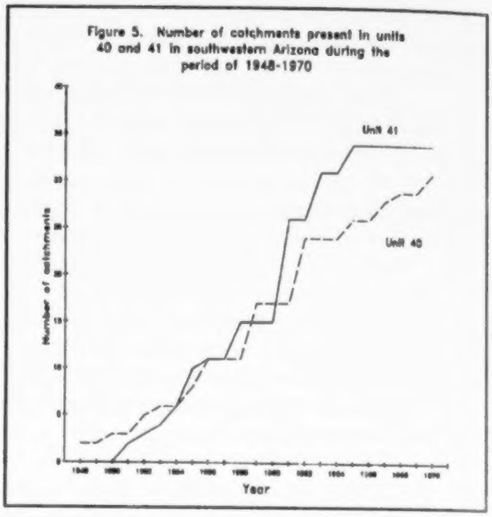
Figure 5. Number of catchments present in units 40 and 41 in southwestern Arizona during the period of 1948-1970

Dissolved oxygen readings for the most part were unremarkable with the exception of Dead Deer Tank, a natural tinaja sampled at 1330 hours on September 18, 1986. The oxygen reading at this deep (2 m), low surface: volume site was 28 mg/1, which converts to 326% saturation at 27.0 C and 634 m elevation. This reading was questionable in that the water sample in the BOD bottle started bubbling following addition of the manganous sulfate reagent. However, the water was very green with Dense sestonic algae, indicating that the potential exists for high levels of primary production (with associated 0_2 production) in these types of waters. Conductivity and alkalinity values for Dead Deer Tank are also exceptionally high. Nitrogen and phosphorous levels for most waters confirmed that adequate nutrients are available for primary production.

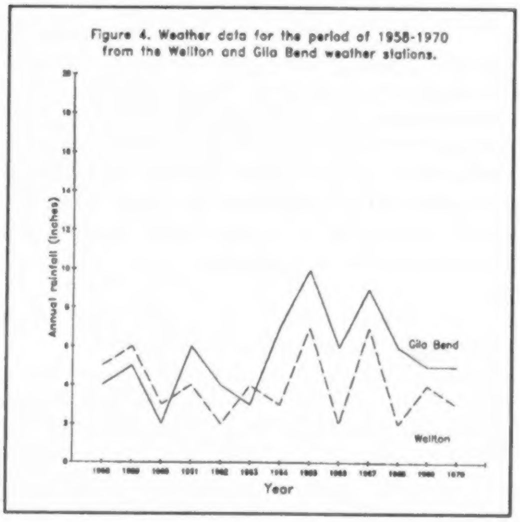
Figure 4. Weather data for the period of 1958-1970 from the Wellton and Gila Bend weather stations.

DISCUSSION

Historic data on the number of deer found in the study area are difficult to obtain. It was not until 1953 that cursory unit narratives were prepared. In 1953, field personnel reported that no deer were present in Unit 40 and that only a few natural water tanks were present (AGFD 1953). In 1960 biologists reported that deer density wasso low in southwestern Arizona that it received very little hunter use (AGFD 1960). Of importance to this report is the indication by field technicians that the most critical environmental factor in controlling deer populations was the lack of permanent water, tied to poor distribution of existing waters (AGFD 1961).

Apparent results of an extensive program of catchment construction in Unit 41 are

Table 1. Water quality and associated parameters for selected wildlife water developments (tinajas and retention dams) in the lower Gila River Drainage, Arizona.

Water	Elevation (ft.)	Surface (ft^2)	Capacity (gal.)	Date	Time
Anvil Tank	2,100	280	8,400	10-02-86	1500
Arch Tank	2,050	130	8,000	11-18-86	1230
Big Jane Tank	1,370	720	700	09-05-86	0845
Black Tank	1,200	260	13,000	12-13-86	1130
Bucket Tank	1,360	200	7,500	09-05-86	1015
Dead Deer Tank	2,080	80	2,400	09-18-86	1330
Don Diego Tank	920	210	3,900	12-28-86	1100
Dripping Springs Tank		210	3,100	08-09-86	0945
Eagle Tank	960	100	1,500	12-28-86	0830
Major Tank	1,400	220	8,100	12-12-86	0945
Saddle Pothole E	890	130	2,900	09-17-86	1245
Saddle Pothole W	890	150	4,200	09-17-86	1200
Saddle Ret. Dam	950	90	2,700	09-17-86	1530
Sand Tank Pothole	3,040	400	12,100	01-05-86	0930
Sauceda Pothole	1,440	200	7,600	12-27-86	1030
Seep Tank Upper	1,400	70	800	09-04-86	1230
Thanksgiving Day Tank	1,800	200	5,700	12-27-86	1300
White Tanks #4	1,280	300	9,000	08-28-86	1030

TABLE 1. Extended

Water	Water Temp (C)	Cond. (uS/cm)	pH	Dissolved O_2 (mg/l)	Alk. %Sat	NO_3-N (meq/l)	PO_4-P (mg/l)	(mg/l)
Anvil Tank	22.5	308	9.3	14	150	1.2	---	---
Arch Tank	16.0	351	7.2	9	85	2.4	1.8	0.9
Big Jane Tank	26.0	246	7.0	7	82	2.4	1.1	1.2
Black Tank	8.0	311	---	11	89	3.2	0.7	0.2
Bucket Tank	30.0	182	8.1	7	88	1.2	1.4	1.8
Dead Deer Tank	27.0	629	7.1	28	326	6.4	---	3.7
Don Diego Tank	9.5	212	6.9	16	135	0.8	0.6	0.2
Dripping Springs Tank	27.5	887	8.7	13	158	4.8	---	---
Eagle Tank	8.5	252	6.3	12	99	2.4	0.7	0.3
Major Tank	7.5	426	7.5	10	79	4.4	0.7	0.2
Saddle Pothole E	28.0	258	8.4	14	173	2.4	0.6	1.1
Saddle Pothole W	25.5	463	7.0	11	130	3.2	0.4	1.1
Saddle Ret. Tank	28.0	504	7.1	7	86	4.8	0.4	2.5
Sand Tank Pothole	---	366	7.6	---	---	2.4	0.6	0.1
Sauceda Pothole	7.5	615	---	6	47	2.0	1.1	0.7
Seep Tank Upper	29.0	259	7.6	9	111	2.4	3.3	1.3
Thanksgiving Day Tank	9.5	133	6.3	6	49	0.8	1.4	0.2
White Tanks #4	28.0	226	8.2	12	146	2.4	0.0	2.5

reflected in the 1969 Annual Report. The area Wildlife Manager indicated that the installation of water catchments throughout Unit 41 over the past 10 years has changed what was mostly "wet weather" range into "year-round" deer range and that deer harvested and number of hunters has soared (AGFD 1969).

The trend of increasing precipitation in the area over time is also a possible factor involved in the observed increases in deer populations and harvest. This variable could certainly contribute to population increases via improvement of range conditions and its associated benefits, and likely has to a certain extent. Since the regression slopes in Fig. 5 are relatively shallow, year to year variance high, and precipitation levels during the period 1960-70 relatively low, we do not consider this the sole factor involved.

The importance of water to mule deer can be demonstrated through inference from radio telemetered individuals. Hervert (1985) monitored distance from water and watering frequencies for two populations of mule deer in desert areas. He found significant differences ($P>0.05$) in distance to free-standing water between hot, dry periods and hot, wet or cool, dry periods. He also investigated the reaction of mule deer when water sources within established home ranges were closed. The three does he studied all moved into areas outside their home ranges to new waters. These data strongly support our findings that water is important to mule deer and areas lacking in water would be avoided by this animal.

A study of Sonoran pronghorn in southwestern Arizona found that this subspecies was found closer to water sources than would be expected if random use occurred. Further, seasonal use patterns varied, with location during the hot dry period significantly ($P<0.05$) closer than those in wet cool periods (Wright and deVos 1986).

Much of the published literature dealing with the need for water developments is based on desert bighorn research. Holloran and Deming (1958) indicated that bighorn use of certain habitats is seasonal because of limited water sources. They indicate that water development has shown to be a practical method to improve populations. Distribution of water sources has been reviewed by several different authors, with the required spacing ranging from two mile intervals in the Santa Rosa Mountains of California, and one water every four miles (Ferrier and Bradley 1970).

Although a multitude of water sources have been built to benefit desert bighorn in Arizona, population levels continue to decline in some areas. Leach (1968) indicated that there had been no startling changes in bighorn populations in the Death Valley National Monument after water was developed and that none were expected. He felt that continued development of water sources was an important step in continued survival of desert bighorn. This concept is especially important as the increase of interstate Highways, powerlines and aqueducts continues to fragment habitats. Placement of waters has been proposed as a possible tool to reverse the impact of population isolation (Remington and deVos 1985).

Placement of new water developments has resulted in bighorn habitat being changed from ephemeral, principally ram use areas, to yearlong areas with mixed groups. Planet Peak in west central Arizona has been surveyed for several years and was used only by rams, with occasional use by ewes during periods of above average rainfall. There was no permanent water source in this area. Approximately 8 years ago, a permanent water was developed on Planet Peak, which currently supports a resident herd of bighorn (AGFD unpublished data).

Morphometries of tinajas and retention dam developments are typically deep, with low surface:volume ratios. Downstream faces of the cross-sectional profiles are usually steep, if not abrupt. Depending on the hydraulics of individual flood events, this configuration is often conducive to trapping particulates as water velocities slow upon exit from the pool.
Regarding retention dam developments, we have notes that the practice of constructing vertical-walled dams may especially cause sedimentation problems. Often 50% or more of the potential volume of a pool in these instances is accounted for by sediment, and several have been abandoned due to complete sedimentation. The department has also torn down dams built at sites which attempted to deepen existing tinajas because of excessive sedimentation, e.g. Big Jane Tank in the Clanton Hills.

Potentially compounding this problem is the practice of placing rock gabion weirs immediately above the pool site. In many instances, these structures slow velocities or divert large volumes of flood flow away from the pool. In such a situation, rather than reducing sedimentation (their original purpose), they may actually do the opposite by reducing or eliminating the flushing effects of floods.

One relatively simple technique of reducing such effects may be to slope the upstream face of a retention dam to something much less than vertical. Although this would entail hauling more material to the sites, its potential benefits in reducing sedimentation, strengthening the dam, and perhaps lessening leakage are probably cost effective in the long run.

Another concern regarding tinaja/retention dam developments involves organic loading. The ostensibly high levels of primary autochthonous production and allochthonous organic input into these types of waters in the arid southwest potentially create conditions whereby oxygen consumption during decomposition creates reducing conditions and production of noxious and potentially toxic substances. Occasional, unexplained local mortalities of bighorn sheep in Arizona may be the result of these phenomena (Monson 1965, Witham et al. 1982). Decreased flushing effects caused by vertical dams and gabion weirs may exacerbate this potential condition.

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SAGE GROUSE USE OF WILDLIFE WATER DEVELOPMENTS IN SOUTHEASTERN IDAHO

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Abstract

Sage grouse (*Centrocercus urophasianus*) use of water developments in southeastern Idaho was evaluated during summers 1986-88. Neither systematic surveys of wildlife water developments or radio-telemetry efforts suggested that grouse commonly use water developments even during relatively dry years. The mean distance of radio-marked male sage grouse to the nearest water development ($x = 1.9$ km, $N = 74$ locations) was less than that for female grouse ($x = 3.6$ km, $N = 109$ locations) ($P = 0.00$). However, most locations for all radio-marked birds were > 1.0 km from water developments. Sage grouse use of water developments may be enhanced by placing developments along migration routes and closer to summer ranges.

INTRODUCTION

Water developments have been used to enhance habitats of numerous wildlife species (Schemnitz 1980, McCarty 1986) and their value to upland game has been recognized for > 30 years (Galbreath and Moreland 1953, Christensen 1954). Water developments have more recently been suggested as a method for enhancing sage grouse summer range (Autenrieth 1981, Autenrieth et al. 1982). This suggestion has been used as part of the justification for a number of water developments in southern Idaho. However, little published information exists to document the importance of water developments to sage grouse.

The purpose of this research was to quantitatively evaluate the use of water developments by sage grouse during the summer (July-September). We tested the hypothesis that the distribution of sage grouse in a relatively low precipitation zone (22 cm) is not related to the distribution of water developments.

This study is an offshoot of a cooperative research project supported by the Idaho Department of Fish and Game and the Bureau of Land Management. We appreciate the field assistance of Wayne Wakkinen, Lucinda Haggas, Frances Cassirer, Derek Stinson and Colleen Stinson. We also thank the many individuals that aided in trapping sage grouse.

STUDY AREA AND METHODS

Research occurred in the Big Desert Planning Unit of the upper Snake River Plain in southeastern Idaho during summers (July-September) 1986-88. The area is characterized by flat to gently rolling terrain with interspersed lava outcrops. Vegetation is dominated by big sagebrush (*Artemisia tridentata*), three-tip sagebrush (*A. tripartita*) and various bunchgrasses. Annual precipitation varies throughout the Big Desert but is generally about 22 cm. Elevation varies from 1200 to 2100 m (Autenrieth 1981).

The Big Desert contains a wintering/breeding sage grouse population that may migrate up to 50 km to summer range (Connelly et al. 1988). However, a small portion of the population is apparently non-migratory (Connelly et al. 1987).

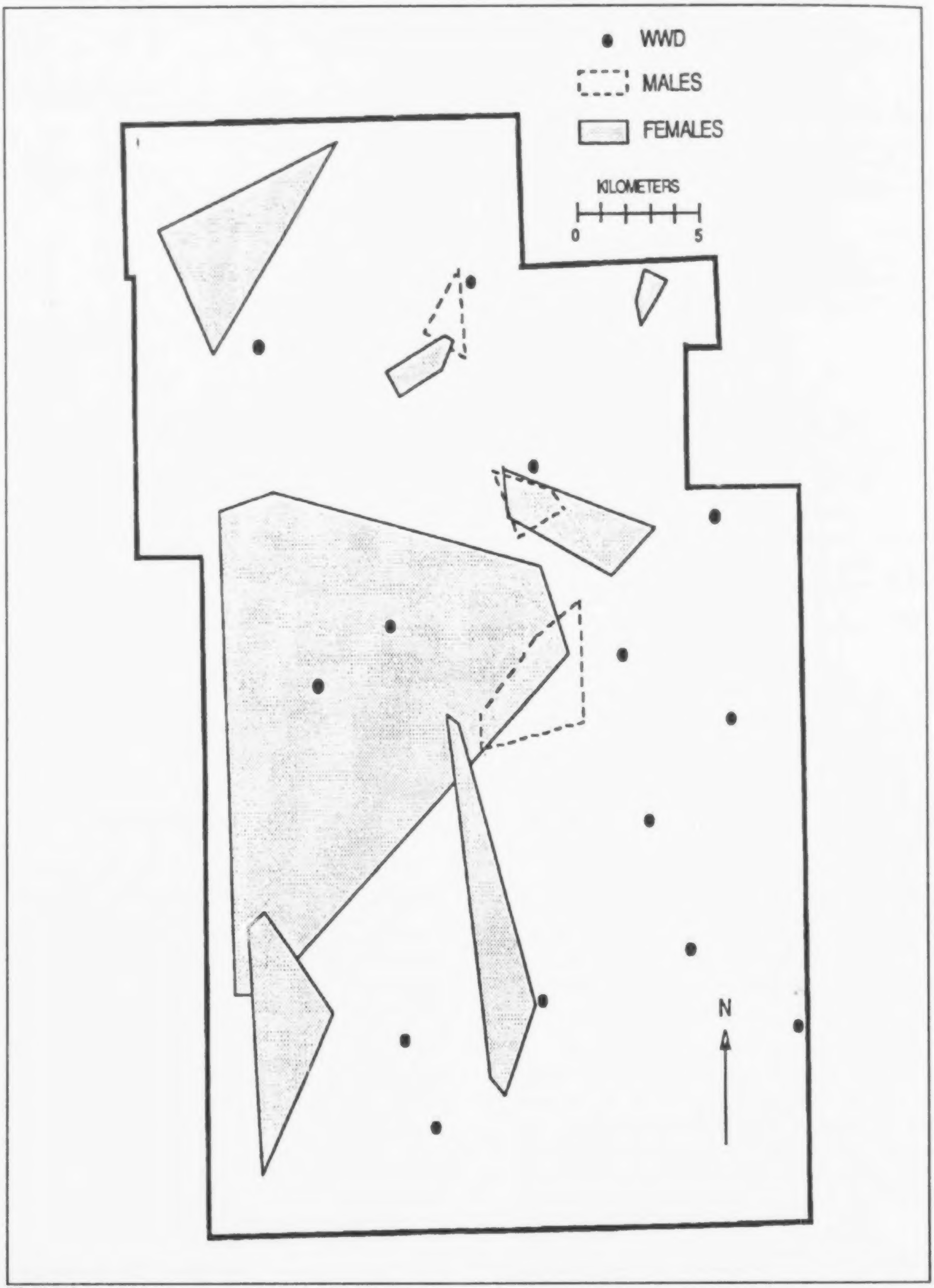
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Figure 1

Since 1981, 28 water developments have been constructed on approximately 1,000 square kilometers of the Big Desert. Our research was restricted to an area of 850 square kilometers in the north-central portion of the Big Desert (Figure 1). The study area contained 16 water developments and four ponds that held water throughout the summers of 1986 and 1987. However, two of these four ponds were dry throughout the 1988 summer. Two types of developments were used. One consisted of a trough with a float to regulate water flow. These troughs were connected to wells developed for livestock. A second type consisted of one or two underground storage tanks. Large aluminum aprons collected precipitation and directed it into openings in the tanks. These openings contained sloped entrance ramps to allow wildlife access to water (McCarty 1986).

We used two methods to assess use of water developments by wildlife. First, developments were systematically surveyed one to two times per week for evidence (i.e. tracks, droppings, feathers, birds) of sage grouse use. After each visit, we removed all existing sign to allow us to better document frequency of use by grouse. After each visit, grouse use was assigned a subjective ranking that varied from 0 (no use) to 3 (unusually high use). An average rating was calculated for each water development at the end of each summer. Radio telemetry was also used to document the importance of water developments to sage grouse. Sage grouse were captured on leks during March and April by nightlighting (Giessen et al. 1982). Birds were fitted with poncho mounted solar transmitters (Amstrup 1980) and monitored one to two times per week during July, August and September. Locations were recorded on 7 1/2" topographic maps and distance to the nearest water development was measured for each location. Home ranges were calculated using the minimum area method (Mohr 1947). Home ranges were only calculated for grouse for which we had > 10 locations over at least a two month span. Statistical comparisons were made using chi square or the Kolmogorov-Smirnov Two Sample Test. Differences were considered significant if $P \leq 0.05$.

RESULTS

Water Development Surveys

Some water developments dried-up in both years, however all developments were refilled by Bureau of Land Management or Idaho Department of Fish and Game personnel after they were reported empty or very low on water. During 1987, water developments contained water on 96 percent of our visits and only one was empty by 2 August. In 1988, developments contained water on only 77 percent of our visits and six were empty by 2 August.

Sage grouse use of all wildlife water developments that we monitored was relatively low during both 1987 and 1988. Only 23 total sage grouse were observed at developments in 1987 and five were observed in 1988 (Table 1). The use index was 0.40 and 0.79 (highest possible score was 3.00) for all developments in 1987 and 1988, respectively. Although some developments were used much more often by grouse in 1988 than 1987 (Table 1) use indices did not significantly differ between years (chi square, $P = 0.26$). The similarity between years likely results from two water developments that were not used at all in 1988. Both of these developments were dry more frequently than the others monitored in 1988.

Radio-telemetry Data

Sixteen of 34 (47%) radio-marked sage grouse monitored during summers 1986-87 remained on the Big Desert. Twenty-three radio-marked grouse were monitored during summer 1988 and none remained on the study area. Of the 16 birds remaining on the study area, we were able to routinely monitor 10 to provide information on grouse use of water developments.

The mean distance of male sage grouse to the nearest wildlife water development was 1.9 km ($N = 74$ radio locations). The mean distance of females to the nearest development was 3.6 km ($N = 109$ radio locations). The difference

Table I. Use of wildlife water developments (WWD) in southeastern Idaho by sage grouse during summers (July-September) 1987-88.

	1987				1988			
WWD	N[a]	Water Present[b]	Use Index[c]	Grouse[d]	N	Water Present	Use Index	Grouse
G-1	8	8	0.75	9	8	8	2.00	4
G-2[e]	6	6	0.83	0				
G-3	11	11	0.36	0	7	4	0.75	0
G-4	12	10	0.10	2	7	6	0.50	0
G-5	8	8	0.25	0	8	8	1.00	0
G-6	6	6	0.67	12	8	2	0.00	0
G-7	11	11	0.64	0	8	8	0.25	0
G-8	6	4	0.25	0	8	6	0.33	0
G-9	11	11	0.09	0	7	3	0.00	0
G-10	10	10	0.10	0	7	4	0.50	0
G-11[f]					8	8	1.75	0
G-12[f]					8	8	1.62	1
Total =	89	85		23	84	65		5
		x =	0.40				0.79	
		s =	0.29				0.71	

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[a] Number of visits to a wildlife water development.

[b] Number of visits when water was present in the water development.

[c] Calculations were based on number of visits when water was present.

[d] Number of grouse observed.

[e] Broken during 1988.

[f] Not monitored in 1987.

between male and female locations with respect to water was significant (Kolmogorov-Smirnov Two Sample Test, P = 0.00). Although males remained closer to developments than females, most radio locations were > 1.0 km from a water development (Figure 2). The closest location for either males or females was 200 m from a development.

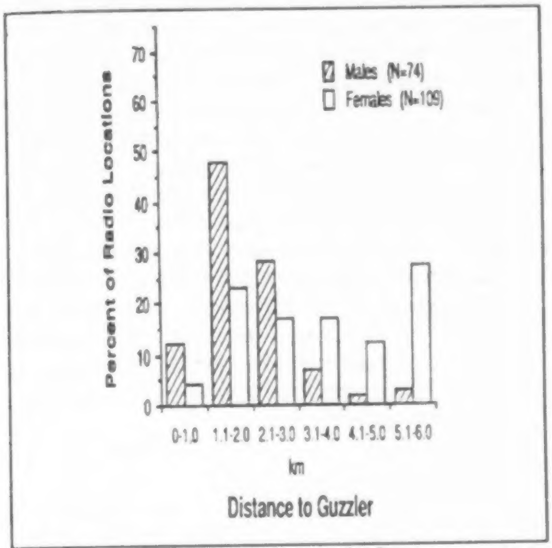

Figure 2. Distance of radio-marked sage, grouse to water developments during summer Kimogorov-Smirnov Sample Test, p=0.00),

Radio locations suggest that sage grouse were not strongly attracted to wildlife water developments. Similarly, a plot of home ranges of radio-marked grouse supports this notion (Figure 1). Sixteen wildlife water developments were available to 10 radio-marked sage grouse that summered on the Big Desert. Only two of these 10 birds had home ranges that encompassed water developments. The home ranges of these two birds included a total of 4 water developments (Figure 1). Both of these birds were females. The mean distance to a development for each of these grouse was 4.1 km (N = 17 radio locations) and 1.6 km (N = 27 radio locations). The distance to the nearest water development for both females ranged from 0.8 km to 6.7 km.

Data obtained from radio-marked grouse will not allow a rejection of the null hypothesis that the distribution of sage grouse is not related to the distribution of water developments. However, we caution that results may differ in other areas and with non-migratory sage grouse populations.

DISCUSSION

Although information on the relationship of big game to wildlife water developments is available (Hervert and Krausman 1986), less is known about the use of water developments by game birds, especially grouse. Moreover, there appears to be a general lack of knowledge pertaining to the importance of free water to sage grouse. The relationship of sage grouse to free water was not mentioned by Braun et al. (1977) in their paper on sage grouse habitat guidelines. Autenrieth et al. (1982) inferred that water was important to sage grouse and suggested that water can be a limiting factor for this species. Autenrieth (1981) indicated that a daily water source is required by sage grouse. Patterson (1952) also implied that water was important to grouse and suggested that it markedly affects the distribution of this species. Despite these contentions, there is little quantitative data available to allow an evaluation of the importance of free water to sage grouse. There is even less information on sage grouse use of wildlife water developments.

During our study, all radio-marked sage grouse left the study area during the driest summer (1988) and moved to agricultural areas or high elevation summer range. This response is probably related to a lack of succulent forbs on the study area, rather than a lack of free water. Water was available to grouse during this summer throughout the study area because of wildlife water developments and stock ponds. Forbs are an important component of the summer diet of sage grouse (Patterson 1951, Klebenow and Gray 1968, Braun et al. 1977, Autenrieth 1981) and because of drought conditions, appeared to be scarce on the study area during the 1988 summer.

The movements and distribution of sage grouse that remained on the study area during summers 1986 and 1987, suggested that grouse were not heavily dependent on water developments. In fact, we could not detect any evidence that any radio-marked sage grouse used a water development. Similar findings were reported by Connelly (1982) for grouse summering in sagebrush habitats. Grouse may obtain sufficient water from consuming succulent vegetation. They may also supplement this source with occasional visits to water developments. However, these visits may be so infrequent that we were unable to detect them through our sampling scheme.

We detected a difference between the location of male and female sage grouse with respect to water developments. This difference may be biological nonsense (i.e. simply a result of our sampling method) or it may reflect a predator avoidance strategy of female grouse. Wildlife water developments attract a relatively large number of animals and thus may serve as a predator "sink". Female sage grouse with broods may avoid these areas because they may increase their exposure, and thus vulnerability, to predators.

Use of water developments by sage grouse may also be related to location of these developments with respect to grouse migration routes and summer ranges. Water developments in our study area were usually installed near natural water sources that dried-up in mid-summer (McCarty 1986). Developments were generally not placed along sage grouse migration routes or near summer ranges because these areas were not well documented. Sage grouse use of water developments might be enhanced if future water sources are placed along known migration routes and relatively close to summer ranges. We should also monitor their use by grouse and other wildlife species to allow an evaluation of their importance. Otherwise, as Robbins (1983) has pointed out, these developments may provide good public relations material, but the rewards in biological terms may not be very apparent.

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WILDLIFE WATER CATCHMENTS
AS MITIGATION FOR
CENTRAL ARIZONA PROJECT CANALS, ROADS AND RESERVOIRS

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Abstract

The Bureau of Reclamation (Reclamation) is constructing the Central Arizona Project (CAP) to carry Colorado River water to Phoenix and Tucson. Wildlife water catchments are being built near the CAP aqueduct to mitigate for habitat losses due to canal construction, to attract deer to canal crossings, and to deter movement to, and potential drowning in, the canal. Additional wildlife waters are being developed to mitigate for road construction and habitat losses associated with dam construction and modification. Through inter-agency agreements with the National Park Service (NPS), U.S. Forest Service (USFS), Bureau of Land Management (BLM), and Arizona Game and Fish Department (AGFD), Reclamation has appropriated approximately $1,120,000 for the construction and/or renovation of 45 catchments. Reclamation will fund a 3-year study to determine the efficiency of the water catchments in meeting the mitigation objectives.

INTRODUCTION

Reclamation is a construction agency within the Department of Interior, responsible for the building and maintenance of dams and water distribution systems in 17 western states. The CAP is a multi-purpose water project designed to provide supplemental water to central and southern Arizona, and southwestern New Mexico.

Structural features of the CAP include construction or modification of three dams, and a concrete-lined canal extending more than 300 miles from the Colorado river to Tucson, Arizona. The system consists of three aqueducts; Granite Reef Aqueduct (GRA), Salt-Gila Aqueduct (SGA), and the Tucson Aqueduct (TA). Construction was initiated in 1973 and water deliveries began in 1985. The costs of all phases of the CAP are expected to approach $4 billion.

Construction of the canal aqueduct system has resulted in the loss of thousands of acres of Sonoran desert scrub habitat, ranging from diverse mixed cacti-palo verde associations to homogenous creosote-bursage associations. Water developments have been utilized extensively as partial mitigation for impacts to wildlife from the CAP. Reclamation has entered into inter-agency agreements with BLM, USFS, AGFD, and NPS for the construction and/or renovation of 45 catchments. Over $1,120,000 have been appropriated for this construction.

ENVIRONMENTAL COMPLIANCE

Federal laws such as the Fish and Wildlife Coordination Act, the Endangered Species Act, National Environmental Policy Act, and Reclamation's own regulations require that biological impacts be minimized to the fullest extent possible. It is Reclamation's policy to "energetically support, on a continuing basis, an environmental program which preserves and enhances the values of the natural and human environment associated with all of its planning, construction, and operation and maintenance programs." An overall Environmental Impact Statement (EIS) was filed for the entire CAP on September 26, 1972, which committed Reclamation to prepare site-specific EIS's for individual CAP features (USDI 1972).

The number and general location of water catchments has been determined primarily

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through recommendations from long-term wildlife telemetry studies (Krausman 1985; AGFD 1983, 1985) and recommendations from wildlife managers familiar with local wildlife populations and water development needs. After the number of catchments needed had been determined, Reclamation entered into inter-agency or cooperative agreements with cooperating agencies. These legally binding agreements document the need for the catchments, and identify funding and construction responsibilities. An integral part of these agreements are details on the type and installation of the catchment and the construction and maintenance costs. Reclamation coordinated with the Fish and Wildlife Service (FWS) in the review of plans and designs submitted by the constructing agency. Funding is on a cost reimbursable basis.

Water catchments on Arizona state lands are being constructed by the AGFD while those on federal lands are either constructed by the AGFD or by the responsible federal land management agency. Evaluations of proposed catchment locations are made by Reclamation and FWS biologists, an AGFD wildlife manager and a habitat development specialist, and a biologist from the responsible federal agency if federal lands are involved. Individuals with experience in wilderness areas or visual impact assessment are included when appropriate.

Reclamation initiates Endangered Species Act consultation with the FWS by requesting a list of species federally listed or proposed to be listed as threatened or endangered that might occur within the catchment construction area. Section 7 of the Endangered Species Act requires federal agencies to take "such action necessary to insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of an endangered species. "Reclamation also determines if any state-listed species will be impacted. Most of the concern to date has been with rare plant species. If any special status plant species are known from the general area, a contract field botanist visits and surveys the site and prepares a biological assessment of the findings. Catchment locations are adjusted to avoid any rare plant species.

Reclamation archaeologists survey the proposed site for cultural resources and submit a cultural resources report with any relocation or mitigation recommendations included. An environmental assessment (EA) on the proposed project is then written by the respective land management agency. Based on the information in the EA a Finding of No Significant Impact (FONSI) is concluded and construction of the catchments begins. Water catchments built for CAP mitigation vary in design to accommodate management goals, land status, physical environment, and the constructing agencies' preference.

CATCHMENTS AS MITIGATION FOR CANAL IMPACTS

Prior to construction of the portion of the canal in western Arizona known as the GRA there was concern that the canal would serve as a barrier to animal movements, and act as a hazardous attractant to desert wildlife seeking water. Native ungulate drowning can be expected when water is introduced into an arid environment in an open canal and this has been a problem in many canals throughout the western United States. Between 1977 and 1979, 89 deer drowned in the Wellton-Mohawk Canal in Southwestern Arizona (Rautenstrauch and Krausman 1986) and 53 deer drowned in the GRA between 1985-1987.

In 1979, the University of Arizona began a 6-year study on the impacts of the CAP on desert bighorn sheep and desert mule deer. The study recommended that adequate fencing be built to keep ungulates out of the canal and bridges be located to facilitate use of habitat on both sides of the canal. Because of the presumed importance of water, building a series of catchments was recommended to "intercept" ungulates before they approached the canal. Water catchments were also recommended to attract deer to wildlife bridges over the canal.

Based on these and other recommendations, Reclamation committed to the construction of 17 catchments along the GRA. On March 5, 1985, Reclamation and the AGFD entered into a cooperative agreement to "furnish, install, operate, maintain, and evaluate wildlife water catchments." This agreement has been amended once and all 17 catchments have been completed. Two catchments were built to serve both bighorn sheep and deer, 14 for deer only, and one exclusively for sheep.

The AGFD has used three basic designs in constructing their catchments on the GRA. Most wildlife water catchments for the GRA mitigation consist of a 10,000 to 17,000 gallon sectional steel storage tank lined with polyvinyl chloride plastic film, a 5,000 square foot catchment apron to collect rainwater, and a float-operated drinking trough. The storage reservoir is usually under the watershed and the drinking troughs are usually constructed of fiberglass although several are made of concrete. The aprons are built as close to ground level as possible to minimize visual impacts and are painted for camouflage. The catchment's apron consists of wood frames with galvanized steel sheeting. Where necessary, each catchment is fenced with a standard wildlife/livestock fence to protect the facilities from livestock and insure water availability for wildlife. The AGFD constructed these catchments for about $14,000 each (material and labor).

Five catchment aprons were constructed using fiberglass matting and a blend of asphalt emulsions sprayed on the natural ground surface. These catchments cost approximately $14,000 each to construct. However, these are now being replaced with metal aprons as they are prone to being damaged during high winds.

In remote areas where steep slopes and rocky substrate prevent installation of the reservoir, small 2,000 gallon fiberglass cylinder storage or "weeny" tanks are used with a check dam to take advantage of natural drainage patterns. This design will be used in the Picacho Mountains sheep water site near the Tucson Aqueduct. One such catchment was built in the Socorro Peak area of west-central Arizona for bighorn sheep to mitigate for the GRA. This catchment cost approximately $7,500 to build.

To provide substitute wildlife water for sources cut off by construction of the SGA, south of Phoenix, Arizona, and as mitigation for associated habitat loss, the Central Arizona Water Control District installed two solar pump-supplied catchments upslope of the SGA. This pumping system consists of two 45 watt photovoltaic modules which drive a 12 volt DC vane pump. The vane pump sucks water from the aqueduct and pushes it up a dirt dike to a buried 300 gallon fiberglass storage tank. Water from the tank flows by gravity down the side of the bank to a valve located about 1 foot above the desert floor. The water is fed into the fiberglass drinking trough by a float valve. The 300 gallon tank contains an electric float switch which breaks the circuit to the pump when the tank is full. The solar day is about 5-1/2 hours in winter and 7 hours in summer. The pump will deliver about 40 gallons per hour. Each unit cost approximately $6,000 to install. Reclamation subcontracted to Arizona Solar Enterprises, Inc., in Scottsdale, Arizona, for construction. Costs of some of the major components include:

- two photovoltaic panels	$1,000
- concrete pumpbox	$ 400
- 1/2" diameter PVC pipe and fittings (95 feet)	$ 570
- sediment filter	$ 60
- underground fiberglass tank (300 gallon)	$ 900
- 12 volt DC motor	$ 350
- float switch	$ 140
- pea gravel (bedding for storage tank)	$ 180

This system is probably not feasible for most wildlife management situations. However, it could be used along other canal systems or at wells with a shallow water table. Maintenance problems encountered to date have been malfunctioning float valves and the pump losing its prime.

CATCHMENTS AS MITIGATION FOR ROAD CONSTRUCTION AND RESERVOIR IMPACTS

Water developments have also been used as mitigation for construction of new roadways associated with the CAP such as the Castle Hot Springs Road at Lake Pleasant, northwest of Phoenix, Arizona, and State Route 88 (SR88), at Lake Roosevelt in central Arizona. There was a concern at Lake Pleasant that upgrading the roads and associated fencing would disrupt big game access to the lake for watering. Water catchments were constructed to off-set this potential barrier. The six Castle Hot Springs Road catchments are on BLM lands and Reclamation and BLM signed an inter-agency agreement for Reclamation to fund and BLM to build these catchments. The BLM design is somewhat different than that of the AGFD. The 10,000 gallon storage tank is covered by a 30' X 82' corrugated metal watershed that is flush with the ground. 'Access to the tank is via a "trap door" built into the apron. Rainfall flows into a gutter which delivers the water to a fiberglass "walk-in" drinking trough. Since the bottom of the trough is level with the bottom of the tank, a float mechanism is not needed to regulate water levels. These six catchments have been built at an approximate cost of $11,000 each and were fenced with pipe to prevent access by wild burros. Four additional catchments are being built north of Lake Pleasant to enhance wildlife habitat and mitigate for habitat losses due to inundation from an increased lake level resulting from construction of a new dam. With the modifications of Roosevelt Dam, the new lake level will inundate an existing roadway (SR88). Since the new upgraded roadway could cause increased wildlife mortality from vehicles, two water catchments were recommended to "intercept" wildlife movements to the lake. These catchments are located on the Tonto National Forest and were built by the USFS. The USFS also uses a corrugated metal apron with a fiberglass storage tank set downslope and float operated drinking trough. These catchments cost approximately $15,500 (material, labor, helicopter time) each to construct.

MAINTENANCE AND MONITORING

Each inter-agency agreement requires the construction entity to monitor maintenance needs and wildlife use of the catchments. For example, as part of the inter-agency agreement with the AGFD, they are responsible for assessing the wildlife use of each catchment. Representatives from Reclamation and AGFD will conduct a field review during the final year of each agreement and every 5 years thereafter to evaluate the condition of the catchments and estimate costs and work requirements for maintenance to be conducted on a 5-year basis, throughout the 50-year life of the project. During the hot summer months, AGFD wildlife managers frequently check the condition and use of the catchments. A yearly report is forwarded to Reclamation to aid in determining if the mitigation is effective.

This past summer Reclamation biological technicians established dust track plots to monitor wildlife use around troughs at the Lake Pleasant catchments. Although use by ungulates was minimal the first year following construction, Reclamation will continue to monitor the site in future years. Remington et al. (1984) found minimal use immediately after catchment construction in southwest Arizona, followed by increased use every year thereafter. Other Reclamation catchments that have been in place for several years are now receiving heavy seasonal use. This may also be related to periodic fluctuations in the local ungulate population levels.

The GRA Final Environmental Statement (USDI 1974) committed Reclamation to a program of environmental research and monitoring during the operational phase of the project to evaluate any ongoing impacts to deer or bighorn sheep and to quantify the effectiveness of wildlife mitigation. The main objective of this monitoring is to determine the effectiveness of water catchments in drawing wildlife away from the GRA, of altering distribution of deer and bighorn sheep, and of mitigating big game drowning losses. Additional objectives include determining the influence of artificial water sources on the carrying capacity of the habitat, documenting any increases in ungulate inter-specific competition, and finding out if these catchments are creating predator "traps." Reclamation has recently contracted with the University of Arizona to attempt to answer these questions. This 3-year study is designed to determine whether water developments are indeed effective mitigation for CAP impacts to desert ungulates.

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Volunteers

USING VOLUNTEERS: BLESSING OR FRUSTRATION

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ABSTRACT

Dollars for on-the-ground wildlife work are scarce to non-existent in this day and age. Congress has left the Federal biologist one option. If the public will help finance a wildlife project, Congress will fund a portion also. This plan has placed great emphasis on the use of volunteers to build wildlife projects using some sort of private-federal-state split on the cost. Water development projects are natural choices for these volunteer efforts. Is the idea of using volunteers on these projects valid, or is the idea just another scheme that looks good but only serves to take more of the biologist's valuable time with few results? Four benefits are perceived to come from using volunteers: 1. Work can be done 2. New ideas can be utilized 3. Maintenance can be improved 4. A wildlife advocacy group is formed. These benefits can be realized, and problems kept to a minimum, by following three rules. These rules are: 1. Think the project through 2. Commit 100% to the project 3. Thank volunteers quickly. Biologists should be trying to do everything possible to benefit wildlife, and right now, using volunteers is one of the ways. Therefore, biologists have a professional duty to try volunteer projects.

INTRODUCTION

The practicing biologists sitting in this room today have a problem. There probably never was a Golden Age when wildlife dollars flowed like honey, but now is certainly not that time. Dollars for on-the-ground wildlife work are scarce to non-existent. Congress has, however, given Federal biologists one option that is being employed and will likely play an increasing part in wildlife programs. Congress said, in essence, that if the public wanted a particular wildlife project, the public should be willing to foot a part of the expense. Congress charged biologists with designing the projects and locating volunteers. When those tasks are complete, applications for Congressional appropriation funding can be made. This plan has placed tremendous emphasis on volunteer programs in Federal land management agencies. The use of volunteers is being practiced by some state wildlife agencies as well, and is probably being considered by other wildlife oriented entities.

If you have not worked much with a volunteer program, you might think that there would be some benefits, but there could also be the potential for monumental problems. Is the practice of using volunteers to complete water projects the blessing that some people say it is, or is it hype, totally frustrating the field biologist charged with actually doing the work?

RESULTS AND METHODS

I have four years of experience using volunteers on wildlife water development projects and am planning a fifth season next year. In my experience, being able to use volunteers translates into a blessing. There are four basic benefits that I perceive as being derived from using volunteers on water development projects.

First is the obvious benefit, it is the only way many wildlife projects can be completed at this point in time. In 1985, two reintroductions of desert bighorn sheep were slated in east central Nevada contingent on a series of wildlife water developments being completed. Contracting such a project or even building it in-house had an estimated price tag of $250,000. The projects were only a dream until placed into a matched-fund context where labor, services, materials and money were given by private individuals and companies. Eleven water developments were completed in three years. The sheep were reintroduced, and the cost of the project package came with only $48,000 of actual federal dollars being spent. Volunteers donated over $89,000 worth of labor and services.

Secondly, volunteers can bring new, cost-saving ideas to projects. One of the groups I have had the privilege of working with is made up of people who work in construction, manufacturing and other trades. These people are invaluable in solving on-site building problems that invariably occur when custom fitting material into a building site. Ideas can come from any direction on these projects, the project biologist just needs to have eyes and ears wide open. In 1986, a man who had only passing interest in wildlife or water developments, was able to solve a problem with collection aprons on fiberglass guzzlers because his hobby was resin casting. The problem would have taken much longer using in-house ideas since the solution required fairly specialized knowledge.

The third benefit is derived from the fact that at work's completion, there will be hundreds of volunteer eyes watching over the project. Reality dictates that a biologist with 1-3 million acres to cover will not be able to visit a project very often. But those persons who donated time, money and materials to a project take a very personal interest in monitoring the water development for success, failure or damage. This fact could be responsible for saving an entire project if one small, but eventually catastrophic flaw is corrected in a timely manner.

The fourth benefit, which is more subtle, is that an advocacy group is formed. Biologist's are subjected daily to boasts that persons in the mining and ranching industry make substantial contributions into improvements on public land and that this investment comes with the right to have a greater say in the management of that land. When sportsmen and other wildlife conservationists make investments such as the $89,000 donation, these groups begin to have a stronger voice in the management of public lands.

These "blessings" in the form of benefits to wildlife and the overall wildlife program do not just happen; there is no "miracle" involved, only work. Does the field biologist have to be subjected to a barrage of new problems to be able to gain the benefits of using a volunteer program? Granted, there are hurdles that have to be crossed with this program just like there are in any other. (Those familiar with the old contract water developments will testify that those were not without problems.) There are few new problems with using volunteers on a water development that cannot be solved with a little thought. Any frustration associated with a volunteer project comes not from using the volunteers, it comes from the lack of thought and planning on the part of the project biologist.

There are three simple rules which I believe will nearly eliminate most hurdles associated with volunteer projects. The more closely these rules are followed, the less frustration a biologist will encounter. These very simple, obvious rules are as follows:

1. Think everything through before a project is ever started.

2. Commit 100 % after a project is chosen for volunteer work.

3. Be as quick to thank the donors as to ask for help.

Let us examine these rules in detail.

THINK IT ALL THROUGH.

Make sure the chosen project is conducive to using volunteers. A fact of life is that some critical projects will not attract volunteers. The site is too remote, the drive too far, the area not scenic enough, the objective too vague and so forth. Look at the project from the average public perspective and ask yourself if you would participate as a volunteer. Answer as objectively as possible. If there are serious doubts, consider looking for another project, at least your first year. For a start, pick a project with high public interest, a so-called "glamour" project. This will nearly eliminate the fatal problem of a high dropout rate at the last minute. If you cannot come up with a "glamour" project, you might try upping the interest in the chosen project with something like a barbecue, or a horseback or helicopter ride to the remote site. Once you have created a pool of volunteers and gained a rapport with them, then go after a tougher project.

After a suitable project has been chosen, think the entire project through from start to finish. Estimate your needs for labor, materials, your time commitment, and make a rough completion timetable. Informally involve your volunteers as early as possible on a construction date. The time that they can work may be radically different than you had in mind for working on a project. Make a list of possible stumbling blocks and determine if any appear to be too big to cross. Make a rough contingency plan to solve any problem you see that might surface. You certainly are allowed to make mistakes on these projects and there will be a few last minute problems to solve just like any other project; a little indepth pre-planning will make sure none of the mistakes or problems are fatal to the project. At this point, there is still time to back out of a project if too many things look doubtful. Do not try to answer all of the questions at first, just do the normal thought while planning including the volunteers.

COMMIT 100%.

Once a volunteer project has been chosen and a certain amount of thought planning has occurred, commit to the project 100%. Make no mistake, commit 100% mentally, not necessarily time wise. One of the hardest things to remember is that volunteers are not being paid for the work like your co-workers or a contractor would be. Keep this non-pay status in mind at all times and give it respect. If volunteers are willing to pay from their own pocket to complete a wildlife project, the project biologist is, in my opinion, obligated to meet the volunteers half way. Make sure that paperwork is done on a project. Stay in informal contact with the volunteers on the project's progress so they know you are serious and are working toward completion. Make sure that parts and tools are assembled when workers show up and that the project can be completed or nearly so in the time you ask the volunteers for assistance. Once a building date is set, do not have to change it because you are not ready. This has a tendency to make the public think the whole agency is not quite on the ball.

Supervisors, the field biologist will need 100% commitment from you too - especially the first year. This generally translates into a few minutes to a few hours to help solve a problem or get a letter out. Do not put off acting on a volunteer project need. Remember. These projects are as close as most will come to total public scrutiny, and the impression made here is critical. Supervisors, if you support projects that will need volunteers, give the project biologist a little room to operate. Allow as much informal contact to occur between the private groups and the person actually doing the work as is needed.

THANK AS QUICKLY AS YOU ASK.

Try to personally thank every volunteer for participating. Remember, this is the only reward these people will get at project completion other than the indirect benefit to wildlife. Absolutely have a written thank you letter in the mail to every person and/or organization that participated within a few weeks after the project is completed. Since the project biologist has probably put off other work to accomplish the volunteer project, it will be hard to find the time to write the thank you's. However, when a volunteer receives a letter thanking him/her, any rough spots the project had will be forgotten and that volunteer will probably commit right then to doing another project in the future. Include in the thank you letter, or in another mailing if necessary, pictures of the volunteers or the project, news articles or certificates of appreciation. At this point, administrative personnel may balk at spending a hundred dollars or less on photo duplication and a second letter mailing when one could wait and send everything all together. Well, in my experience, photo duplication and/or articles can take months. In the meantime, the project gets colder, time gets filled with other jobs, and the thank you becomes less important. Eventually, it is never sent, and you lose people because they think they were taken for granted. Faithful practice of this last rule will garner the project biologist thousands of dollars of benefits in the future-guaranteed!

CONCLUSIONS

One last item as to why volunteers should be considered on wildlife projects is that I believe it is the professional duty of every biologist to try any and all programs that could benefit wildlife. Right now, using volunteers is one of the main ways available and biologists are duty bound to give it a try. Many things that a volunteer program entail are completely foreign to the experience, education or interest of the biologist who often sees himself/herself as the lone wolf who shuns people. The volunteer project biologist must practice salesmanship, psychology and fund-raising techniques. Not every biologist is going to be as good at it as some. However, in my opinion the small project with just biologist and a couple of buddies is equal to the large project where numbers of people are great and logistics are complex. You cannot really fail at a volunteer project once it has begun because you will be doing everything in your present power to benefit wildlife, and that fact is more than some small part of our job, it is the whole ballgame.

AFFILIATIONS OF VOLUNTEERS PARTICIPATING IN CALIFORNIA WILDLIFE WATER DEVELOPMENT PROJECTS

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Abstract

Affiliations of persons associated with California's Volunteer Desert Water and Wildlife Survey from 1974-1985 were determined. Individuals with no affiliation provided the greatest amount of participation, while organized sportsmen provided the greatest amount of participation among organized groups. Participation by persons affiliated with protectionist organizations was low. It appears as though advertising has a major impact on participation from year to year.

Keywords: Affiliations, California, coordination, habitat improvement, mountain sheep, Ovis canadensis, volunteerism.

INTRODUCTION

The literature is replete with information related to the views and characteristics of both consumptive and non-consumptive users of wildlife (Klein 1973, Peterle and Scott 1977, Shaw et al. 1978, Witter and Shaw 1979, Shaw and King 1980, Kellert 1980a, 1980b, Lyons 1982, Shaw and Mangum 1984, and many others). Additionally, an increasingly common theme is that wildlife belongs to consumptive and non-consumptive users alike, and that managers must consider the interests of both groups in formulating wildlife programs (DeGraaf and Payne 1975, Fazio and Belli 1977, Shaw et al. 1978, Witter 1979, Witter and Shaw 1979, Shaw and King 1980, Lyons 1982, Shaw and Mangum 1984, and others) Indeed, there is a need for a coalition between consumptive and non-consumptive users to work together to insure adequate funding for, and incorporation of nongame objectives into wildlife management programs (Madson and Kozicky 1971, Shaw et al. 1978, Witter and Shaw 1979, Shaw and King 1980, Shaw and Mangum 1984, International Association of Fish and Wildlife Agencies n.d., and others). One way to insure that persons with diverse interests in wildlife have an opportunity to contribute to wildlife management is through volunteer programs (Wilbur 1978, Smith 1974). Additionally, there are many indirect benefits to wildlife programs which result from a better informed, more involved public (Smith 1974).

Although active wildlife-oriented volunteer programs are ongoing in several southwestern states, I am unaware of any attempt to determine the affiliations of persons participating in such programs. In this paper, I describe the affiliations of participants in California's Volunteer Desert Water and Wildlife Survey (VDWWS), an informal organization of volunteers interested in constructing water developments for desert wildlife, particularly mountain sheep (Ovis canadensis).

In California, mountain sheep were a nongame species from 1878-1986. As such, no sport hunting for that species occurred for over 100 years (Wehausen et al. 1987). Because mountain sheep are a highly visible and popular species, volunteer habitat improvement projects attract a great deal of interest, from across a wide spectrum of interest groups (Bleich et al. 1982). From 1974-1985, volunteers participated in 56 major water development projects, resulting in the construction of artificial water sources, the improvement of natural desert water sources or the maintenance of existing artificial water sources, for mountain sheep (Ovis canadensis); Bleich et al. (1982) have provided a general description of these projects.

I thank the participants in the VDWWS for their cooperation in providing their affiliations on registration forms. L.J. Coombes, J.H. Davis, J.D. Massie, G. Mulcahy, and A.M. Pauli, California Department of Fish and Game (CDFG) have provided able leadership for the volunteer program over the years. G. Sudmeier and D. Jones served as water project coordinators for the Society for the Conservation of Bighorn Sheep (SCBS). SCBS and the sportsmen of California deserve much credit for their role in founding this volunteer program, and for their continuing support. Preparation of this paper was supported by the Sacramento Safari Club, SCBS, and the California Association of Professional Scientists, while I was on leave of absence from CDFG, at the Institute of Arctic Biology, University of Alaska, Fairbanks.

METHODS

Data included in this paper were collected from volunteers participating in projects directly supervised by CDFG personnel. All volunteers completed a waiver of liability and filled out a registration form prior to beginning work on any given project. Registration information requested included the individual's affiliation, if any. Registration information was later transferred to a separate data file. All registrants were categorized into one of seven categories for purposes of this analysis: Society for the Conservation of Bighorn Sheep; other sportsmen's clubs; school groups; scout groups; protectionist groups; and "other" organized groups. Those persons not indicating an affiliation on their registration form were categorized as "individuals". It was assumed that the rate at which registrants indicated an affiliation was constant across all groups.

A Friedman 2-way test (Siegel 1956) was used to compare participation by the various groups across years, and to compare participation by years, across groups.

RESULTS

Between 1974 and 1985, 2,616 participants in VDWWS contributed 7,848 man-days of labor to the California Department of Fish and Game for the purpose of constructing or maintaining water developments for mountain sheep (Table 1). Individuals, with no stated affiliation, contributed 38.7% of the total labor, and those persons affiliated with sportsmen's organizations (SCBS and other sportsmen's organizations combined) contributed 31.9%, followed by school groups (17.9%), scout groups (6.3%), protectionist organizations (2.6%), and others (2.5%). The latter category included organizations such as 4-H clubs, off-road vehicle clubs, and church groups.

The distribution of workers differed over a 12-year period, 1974-1985 ($P<0.001$, $X_r^2 = 38.17$, 5 df). Persons indicating an affiliation with sportsmen's clubs contributed the highest percentage of labor recorded in 7 of 12 years; in those years in which other categories exceeded sportsmen's contributions, school groups contributed a greater percentage of labor one year (1977) and individuals contributed a greater percentage during four years (1982-1985).

A difference existed in the way that the amount of volunteer labor was distributed over the same 12 year period ($P<0.01$, $X_r^2 = 29.67$, 11 df); in fact, 79.3% of the effort occurred during those years in which the projects were heavily advertised, either in a popular, widely distributed newspaper article (1977), or through CDFG news releases (1981-1985). Although more projects occurred during years with advertising (36;1977, 1981-1985) than during years without advertising (20;1974-1976, 1978-1980), the overall participation rate per project (57.6) for projects that were advertised was more than double that (27.2) during years in which no advertising occurred.

DISCUSSION

Participants in California's VDWWS come from a diversity of backgrounds, but group participation rates are highly variable. Among organized groups, sportsmen have contributed a consistently high proportion of the effort in VDWWS (Table 1). Members of the Society for the Conservation of Bighorn Sheep have accounted for 53% of the total participation by organized sportsmen.

Organizations associated with secondary schools or colleges have been major contributors to VDWWS for many years, although annual participation has been quite variable (Table 1). The large amount of participation in 1976 and

1977 maybe a reflection of the great interest created by the "ecology movement" of the 1970's, combined with active recruiting in 1977. Advertising also may explain large numbers of participants from school groups during 1981 and 1982 (Table 1).

Table 1. Participants in mountain sheep habitat improvement projects sponsored by the Volunteer Desert Water and Wildlife Survey, 1974-1985. The 2,616 participants contributed 7,848 man-days of labor during this period.

	Number of Participants, By Category						
Year	SCBS	Other Sportsmen	Students	Scouts	Preservationists	"Others"	Individuals (no Affiliation)
1974	10	5	1	1	3	0	1
1975	21	25	18	3	4	0	4
1976	25	21	42	7	9	0	12
1977	15	54	125	63	23	7	54
1978	24	17	3	10	1	0	24
1979	27	27	13	3	5	0	45
1980	53	10	46	2	1	1	19
1981	81	38	120	2	8	9	87
1982	43	41	45	32	3	23	208
1983	30	62	27	11	6	21	211
1984	36	32	15	0	0	3	195
1985	54	59	13	32	4	2	152
TOTALS	**446**	**391**	**468**	**166**	**67**	**66**	**1,012**
MEAN	37.2	32.6	39.0	13.8	5.6	5.5	34.3
SD	18.1	17.9	40.1	18.3	5.9	7.9	80.2
CV	0.49	0.55	1.03	1.33	1.05	1.44	0.95
% OF TOTAL	**17.0**	**14.9**	**17.9**	**6.3**	**2.6**	**2.5**	**38.7**

Participation by Scouting Organizations has been variable. High participation rates likely are a reflection of scouting organizations "adopting" a particular project(s) as their "own". A large increase in participation by scouting organizations in 1977 likely was a result of the advertising which occurred in January of that year.

Participation by persons affiliated with protection-oriented organizations, and with "other" types of organizations has remained low, at 2.6% and 2.5%, respectively, of the total participation between 1974 and 1985. Persons affiliated with both categories appeared to respond positively to advertising in 1977, and "others" responded particularly well from 1981-1983 (Table 1).

Overall, persons who did not indicate an affiliation contributed the greatest volunteer effort between 1974 and 1985. Members of this category responded very well to published requests for assistance during 1977 and 1981-85 and, since 1981, have contributed 50.1% of the total effort.

Volunteers have been an integral part of wildlife habitat management programs in California for many years (Carpenter 1976, Bleich et al. 1982, Massie 1975, Lindenmeyer 1983). Indeed, the vast majority of the major habitat improvement projects for mountain sheep have been conducted by volunteers (Bleich et al. 1982). Similarly, in Nevada and Arizona volunteers have been a major source of assistance to agencies charged with the management of wildlife (Carson 1972, Ciliax 1972, Welsh 1974, Werner 1984, Suminski 1987). Widespread wildlife-related volunteer programs also are becoming prominent in other parts of the United States. For example, Johnson (1985) noted the importance of volunteerism in rehabilitating streams used by anadromous fishes. Such programs bring together a diversity of individuals with an interest in a common objective.

Shaw and King (1978) and Shaw et al. (1980) noted the desirability of enlisting the support of consumptive and non-consumptive wildlife enthusiasts in management programs. Indeed, I believe that non-hunters and hunters can work together to benefit wildlife. Bleich et al. (1982) noted that consumptive and non-consumptive users alike benefitted from the opportunity to work side-by-side on a specific wildlife-related project, and that they often discovered a need to alter their stereotyped opinion about each other. Clearly, one of the primary benefits of such volunteer projects is the opportunity which they provide for increased dialogue between different factions with sincere concerns for wildlife.

Consumptive users have been major long-term supporters of wildlife management programs. However, the Volunteer Desert Water and Wildlife Survey has provided an opportunity for interested individuals, as well as a number of organized groups from a variety of interest areas, to cooperate with the California Department of Fish and Game. It appears as though the interest in such projects is strong; however, participation by different interest groups occurs at dramatically different levels. While individuals currently provide the majority of the labor donated to VDWWS, sportsmen continue to contribute the greatest amount of labor among organized groups, and participation by those affiliated with protectionist organizations remains low. This remains an enigma, because mountain sheep were fully protected in California beginning in 1878 (Wehausen et al. 1987) and remained so until 1987.

Because there are many indirect benefits to wildlife programs which result from a better informed, more involved public (Smith 1974), it is disappointing that VDWWS has not received greater participation from persons affiliated with protectionist organizations. It is encouraging, however, that unaffiliated individuals and organized sportsmen continue to support VDWWS at high levels. Indeed, in a survey conducted by Witter and Shaw (1979), nearly all respondents felt that non-hunters and hunters can work together in at least a few ways for wildlife, and large percentages of those groups felt cooperation can take place in many ways. I conclude that the interchange of ideas and the mutual support shown for wildlife by the diverse participation in VDWWS will continue to benefit wildlife as avenues of communication continue to open.

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Photo Courtesy of E.M. Blair. August, 1915 quail hunters at Tule Spring water development near Lida, Nevada.

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